DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 333

GROUND WATER

IN

BOXELDER AND TOOELE COUNTIES UTAH

BY

EVERETT CARPENTER

WASHINGTON
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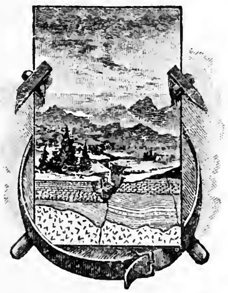

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GROUND WATER IN BOXELDER AND TOOELE COUNTIES, UTAH.

By Everett Carpenter.

INTRODUCTION.

The area covered by this report includes Boxelder County, Utah, the eastern part of Tooele County, Utah, and some small tracts in southern Idaho. It comprises about 9,500 square miles, or more than the combined area of Massachusetts and Rhode Island. It lies between 40° and 42° north latitude and 112° and 114° west longitude. (See fig. 1.)

Insufficient rainfall and the rapid settling of the country have created a demand for an investigation to determine the feasibility of irrigating by the use of underground water. In response to this demand and in order to classify the land under the enlarged homestead act, the writer made an investigation covering a period of four months during the summer and fall of 1911. The greater part of this time was spent in Boxelder County, but two weeks at the close of the season were devoted to a reconnaissance in Tooele, Rush, and Skull valleys, in Tooele County. W. B. Heroy, of the United States Geological Survey, collected most of the data presented for southern Idaho.

PHYSIOGRAPHY.

GENERAL FEATURES.

The area under consideration lies almost entirely in the Great Basin and includes most of Great Salt Lake. West and southwest of the lake and only a few feet above it stretches a vast, flat, barren alkali tract known as the Great Salt Lake Desert. North and south of the flat and lake are isolated mountain ranges, which trend in a general north-south direction and attain elevations of 8,500 to 9,500 feet above sea level, or 4,300 to 5,300 feet above the level of the lake. These ranges are separated from one another by broad, open structural valleys which ascend gradually from the lake or desert, into which they drain. On the east side of the area the lofty Wasatch Mountains rise precipitously to a height of 9,500 feet above sea level and separate this area from Cache Valley and the eastern plateau.

The most pronounced of the larger topographic features are the steep mountain walls that border some of the valleys, the pink and

gray colors of the outcropping ledges being plainly visible to the naked eye for miles. These escarpments have evidently been produced

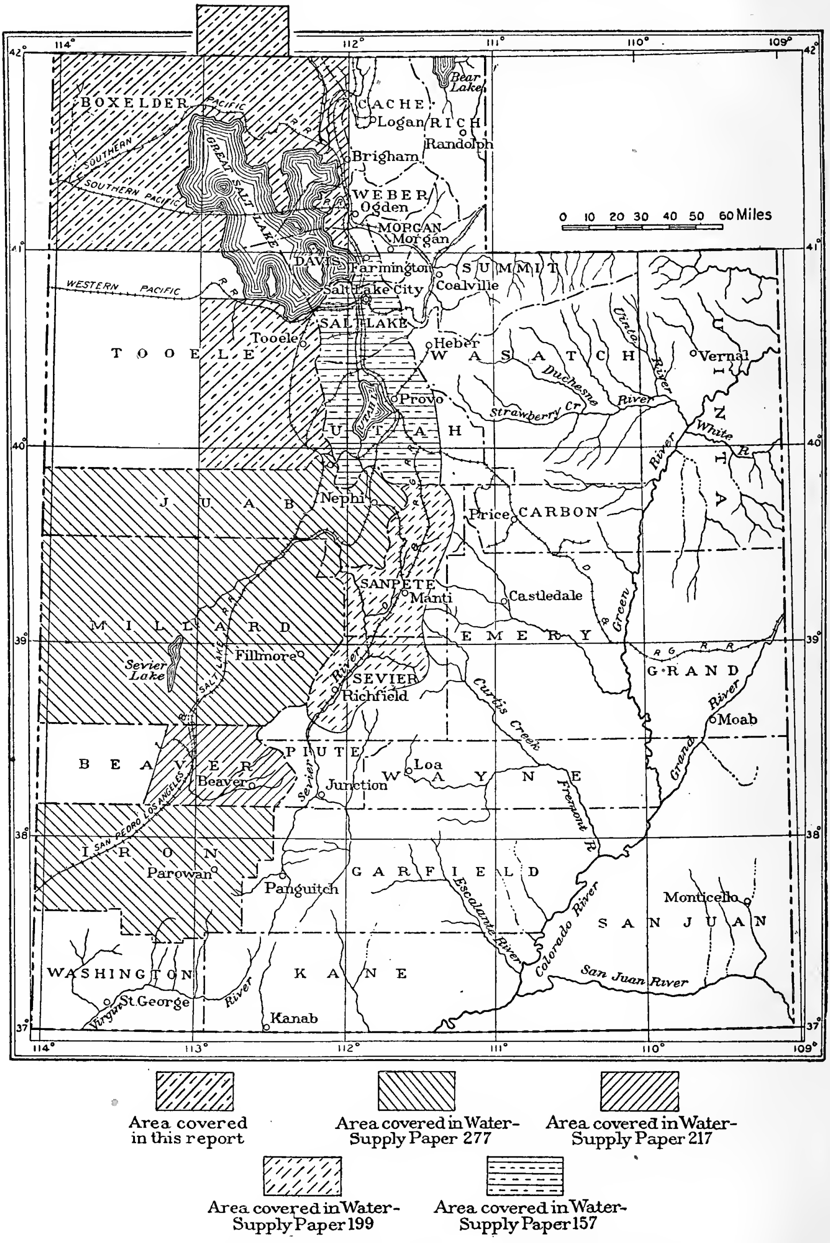

FIGURE 1.—Map of Utah and a portion of Idaho, showing areas investigated.

through extensive faulting movements whereby the earth's crust has been broken into great blocks that were upheaved, tilted, and folded.

This faulting was probably the most important single factor in the development of the present relief of the region and in the production of the system of more or less parallel mountain ranges and structural valleys.

STREAM TOPOGRAPHY.

Superimposed on the features resulting from the diastrophic movements are those produced by running water. The intermittent and permanent mountain streams have given rise to two sharply contrasted types of topography—one the result of erosion and the other of deposition. In their upper courses, where their gradients are steep, the streams erode rapidly and create intricately carved surfaces, but in their lower courses, where they are more sluggish and their waters are dissipated by percolation and evaporation, they deposit the sediments which they have taken from the mountains and build gently sloping alluvial fans.

LAKE TOPOGRAPHY.

The forms produced by faulting and folding and by running water have been modified by those which have been created by the waves of an ancient lake and which present a bold contrast to the oblique lines produced by stream action. Along the mountain sides and on the alluvial slopes are cliffs, terraces, beaches, bars, and spits that could have been produced only by standing water. These shore features were formed at every level at which the lake stood long enough to produce them, but they are most prominent at two horizons known as the Bonneville and Provo levels, about 1,100 and 625 feet, respectively, above Salt Lake. The alkali flat or desert which is so prominent in Boxelder and Tooele counties is the floor of the ancient lake.

Since the desiccation of the lake the topographic features have been but slightly modified, practically the only changes having been wrought by the stream action that has dissected the upper parts of the alluvial slopes, and in some places by recent faulting.

GEOLOGY.

FORMATIONS.

The rocks exposed in this region range in age from pre-Cambrian to Recent.

In Boxelder County quartzites, mica-bearing schists, and gneiss, which are probably of pre-Cambrian age, are exposed in Promontory, Black Pine, and Raft River mountains.

In the northern Wasatch Range Paleozoic formations consisting chiefly of limestone and quartzite but including also shales and sand-

stones are well developed, and apparently all the Paleozoic systems are represented. In the section of these mountains studied by Blackwelder [1] the Cambrian system consists of 2,000 to 6,000 feet of limestone, shale, and quartzite separated by an unconformity from an older quartzite, presumably of Algonkian age; the Ordovician, of about 1,500 feet of quartzite and limestone; the Silurian, of about 400 feet of limestone; the Devonian, of about 750 feet of limestone; and the Carboniferous, of about 4,000 feet of limestone, chert, and shale, representing the Mississippian, Pennsylvanian, and Permian series.

Paleozoic rocks, consisting chiefly of limestone and quartzite, constitute the greater part of the mountain ranges of Boxelder County, but in several places they have been intruded and partly concealed by eruptive rocks of later age. These rocks were studied prior to 1872 by Hague and Emmons,[2] who give a section of Paleozoic rocks consisting mainly of quartzites and limestone and having a thickness of 20,000 to 36,000 feet.

In Tooele County the Paleozoic rocks are exposed in the Oquirrh, Onaqui, and Cedar mountains and are in general similar to those in the Wasatch region. In the Oquirrh Mountains limestones, quartzites, and sandstone of Cambrian and Carboniferous age are exposed, but the other Paleozoic systems are unrepresented.[3] The Paleozoic strata are cut by many dikes of porphyry and monzonite. The Paleozoic rocks in the Tintic mining district,[4] somewhat south of the area described in this report, are described as follows:

> The Paleozoic section in the Tintic Mountains includes 7,000 feet of Cambrian quartzite capped with clay slates and 6,650 feet of limestone with a very few sandy beds, of which the upper 5,150 feet are determined from fossil remains to belong to the Carboniferous. This sequence in the Paleozoic strata is similar to that which has been studied in the Oquirrh Mountains, which form the continuation of this range to the north. In the Oquirrh Mountains, however, the upper portion of the series is much more fully represented, indicating an erosion of many thousand feet of strata in the Tintic Mountains.

Mesozoic strata have not been found in these counties, but they are known to occur in the plateau region to the east and their presence in this area also may be revealed when a more detailed study has been made.

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[1] Blackwelder, Eliot, New light on the geology of the northern Wasatch Range: Bull. Geol. Soc. America, vol. 21, 1910, pp. 517-542. See also Boutwell, J. M., Geology and ore deposits of the Park City mining district, Utah: Prof. Paper U. S. Geol. Survey No. 77, 1912. Blackwelder, Eliot, Phosphate deposits east of Ogden, Utah: Bull. U. S. Geol. Survey No. 430, 1910, pp. 536-551. Richards, R. W., and Mansfield, G. R., The Bannock overthrust: Jour. Geology, vol. 20, No. 8, Nov.-Dec., 1912, pp. 681-709.

[2] Hague, Arnold, and Emmons, S. F., Rept. U. S. Geol. Expl. 40th Par., vol. 2, 1877, p. 340.

[3] Emmons, S. F., Keith, Arthur, and Boutwell, J. M., Economic geology of the Bingham mining district, Utah: Prof. Paper U. S. Geol. Survey No. 38, 1905, p. 33.

[4] Tower, G. W., Smith, G. O., and Emmons, S.F., Tintic special folio (No. 65), Geol. Atlas U. S., U. S. Geol. Survey, 1900.

Thick beds of soft, white, marly limestone, containing abundant fossils of Tertiary age, were found in the Wasatch Range east of Plymouth settlement. They occur high up on the side of the pass and have given rise to great bowlders that have rolled down the mountain side. Heavy beds of conglomerate, limestone, and clays, probably of Tertiary age, are exposed in Park Valley. Sediments consisting chiefly of clay, sandstone, and volcanic ash, and referred to the Pliocene by the King Survey, are exposed in Grouse Creek valley.

Stream, lake, and wind deposits, consisting chiefly of unconsolidated sands, clays, and gravels, lie beneath the alluvial slopes and desert flats, where they extend to an unknown depth. Coarse stream deposits are found along the mountain borders, and fine sediments, chiefly lake deposits, lie in the central parts of the valleys. Wind deposits, consisting of loose sandy material, are found in Curlew Valley near Holbrook, Idaho, and in a few other localities, but they are not prominent in this region. These unconsolidated sediments, which are collectively known as valley fill, are probably Tertiary, Pleistocene, and Recent in age. They no doubt rest unconformably on the older strata which outcrop in the mountain areas. The following incomplete log of a well near Farmington furnishes a typical section of the valley fill: [1]

Log of the Guffey & Galey well, 1 mile southwest of Farmington, Davis County, Utah.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and sand, occasional wood	170	170
Sand and gravel	30	200
Greenish micaceous sand and gravel	100	400
Fine gray clay with fresh-water shells	70	490
Fresh-water shells	......	500
Fine sand	60	570
Coarse gravel, one-half to 1 inch in diameter, from igneous rocks	30	660
Coarse sand, partly from schists	30	730
Coarse gravel and fine sand	40	770
Angular fine gravel	25	795
Greenish cemented gravel and micaceous sand	90	900
Green sand, coarse waterworn gravel, with blackened wood	300	1,200
Green sand and rounded gravel	50	1,250
Sand and gravel	50	1,300
Rounded gravel, quartz sand, occasionally cemented by pyrite, wood fragments	100	1,400
Angular gravel, quartz sand, with pyrite and many bits of wood	110	1,510
Brown earthy micaceous sand, possibly some gypsum	15	1,525
Angular quartz sand	35	1,560
Fine sandy olive-colored clay	10	1,570
Greenish gravel and sand	20	1,590
Gravel, quartz, and micaceous sand	13	1,610
Brown earthy clay and sand	10	1,620
Olive-colored clay, sand, and gravel	20	1,760
Green clay, fine waterworn gravel	40	1,830
Greenish clay	10	1,840
Fine quartz sand, with pyrite and mica	5	1,845
Brown earthy micaceous sand	10	1,855
Pinkish clay and sand	10	1,875
Fine sand	20	1,895
"Bowlders"	......	2,000±

[1] Boutwell, J. M., Bull. U. S. Geol. Survey No. 260, 1904, pp. 471-472.

Lava flows, usually associated with Paleozoic rocks but in some localities in contact with Pleistocene deposits, are found in Hansel, Curlew, and Park valleys. They appear to belong to the Tertiary period.

STRUCTURE.

The larger structural features exhibited in northwestern Utah have been produced mainly by block faulting, a fault scarp being present on one or both sides of most of the mountain ranges. This kind of faulting, which is present in most of the Great Basin, has produced the type of structure known as "basin ranges." The block faulting has been accompanied in many places by folding and thrust faulting, which has rendered the geology very complex.

GEOLOGIC HISTORY.

PRE-PLEISTOCENE TIME.

Rocks containing marine fossils of Paleozoic age are found in many places over the area described in this paper, and it is therefore certain that this part of the State was covered by the ocean during at least a part of Paleozoic time. Mesozoic rocks are not known in this area, but are found in the plateau to the east, and it is therefore probable that this part of the basin emerged from the sea before the beginning of the Mesozoic era. Tertiary beds are found in parts of the area, especially in Malad, Curlew, Park, and Grouse Creek valleys, and their occurrence shows that the region was at least partly subject to lake or river deposition in the Tertiary period.

The diastrophic movements which were instrumental in creating the relief of northwestern Utah probably extended over long periods. They may have had their beginning in the Paleozoic era and perhaps occurred also in the Mesozoic, but the youthful topography and lacustrine history of the region indicate that the present relief was chiefly produced more recently, probably in late Tertiary time.

PLEISTOCENE EPOCH.

During the Pleistocene epoch western Utah held a great inland sea or lake which has been studied and described by G. K. Gilbert,[1] who named it Lake Bonneville, after the man who made the first exploration of the region. (See fig. 2.)

When at its highest stage, this ancient lake stood about 1,000 feet above the present level of Great Salt Lake, or approximately 5,200 feet above the present sea level and had a length of 346 miles and a breadth of 145 miles. Its shore line, exclusive of the islands, was

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[1] Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890.

2,550 miles long and inclosed a water surface of 19,750 square miles, or about 9 times the area of Great Salt Lake.

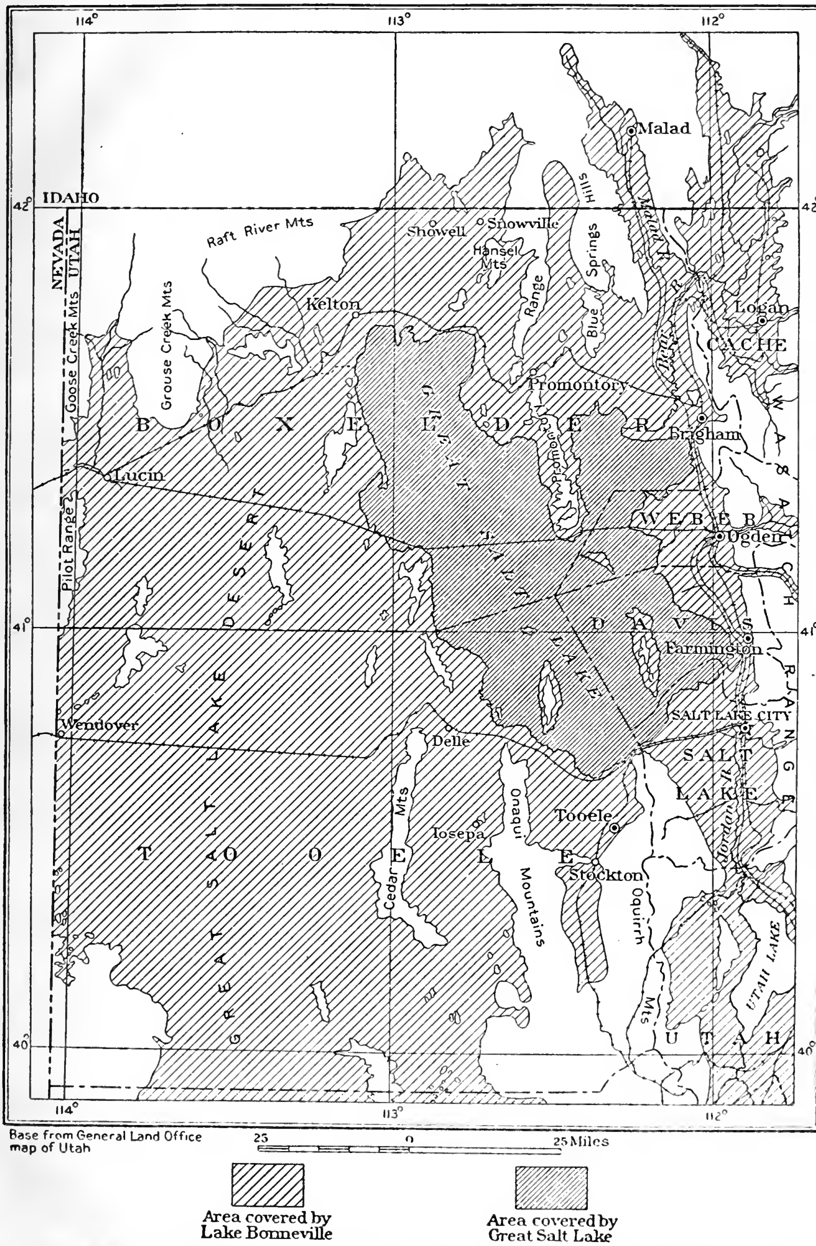

FIGURE 2.—Map of Boxelder and Tooele counties, Utah, showing area covered by Lake Bonneville. (After G. K. Gilbert, Mon. U. S. Geol. Survey, vol. 1, 1890.)

If Lake Bonneville existed at present, the post offices at Grouse Creek and Park Valley would be near its shore, Kelton, Corinne,

Promontory Point, and Grantsville would stand in nearly 1,000 feet of water, and Old Promontory Station, Tooele, Stockton, and St. John would be covered by about 300 feet of water. The map given in figure 2 shows that at the time the lake stood at its highest level the largest body of mainland in Boxelder County was formed by the Raft River, Grouse Creek, and Goose Creek mountains, and the largest in Tooele County by the Deep Creek Mountains. It also shows that the Upper Promontory, Blue Spring, Oquirrh, and Onaqui mountains were peninsulas and that the Cedar, Lakeside, Pilot, Silver Island, Newfoundland, and Terrace mountains and the southern part of the Promontory Range were large islands.

In the humid Pleistocene epoch the waters of the ancient lake rose and fell in a manner not unlike those of the present lake, but through a much wider range. When the lake reached its highest level, which is marked by the Bonneville shore line, it found an outlet at the north end of Cache Valley. The waters discharging through this outlet rapidly cut a channel through the uncemented alluvium, which is here about 375 feet thick and rests on indurated limestone. By this process the lake level was lowered about 375 feet in a comparatively short time. When the limestone was reached, however, the erosion of the outlet proceeded at an exceedingly slow rate, and consequently the lake remained at practically the same level during all the rest of the time that it overflowed, and at this level its waves formed the features of the Provo shore line.

When the climate once more became so arid that the quantity of water evaporated from the lake exceeded the quantity poured into it, the lake level fell and the outlet became dry. During the remainder of the life of Lake Bonneville the water level oscillated and shore lines still plainly visible were carved at lower levels.

The Bonneville and Provo shore lines, which were originally horizontal, are so no longer, a fact which shows that gentle deformation has occurred since they were produced. Recently formed fault scarps near Honeyville lead to the conclusion that faulting is also still in progress in western Utah.

RECENT EPOCH.

The present lake is but a remnant of Lake Bonneville, which, owing to the aridity of the climate that followed the Pleistocene epoch, was gradually reduced in size and depth until an equilibrium was reached between evaporation and precipitation, resulting in Great Salt Lake. As both precipitation and evaporation are variable, however, the level at which the water stands is not stationary, but has fluctuated through a range of about 16 feet in the last 60 years. During most of the period since 1850 a record of the elevation of the

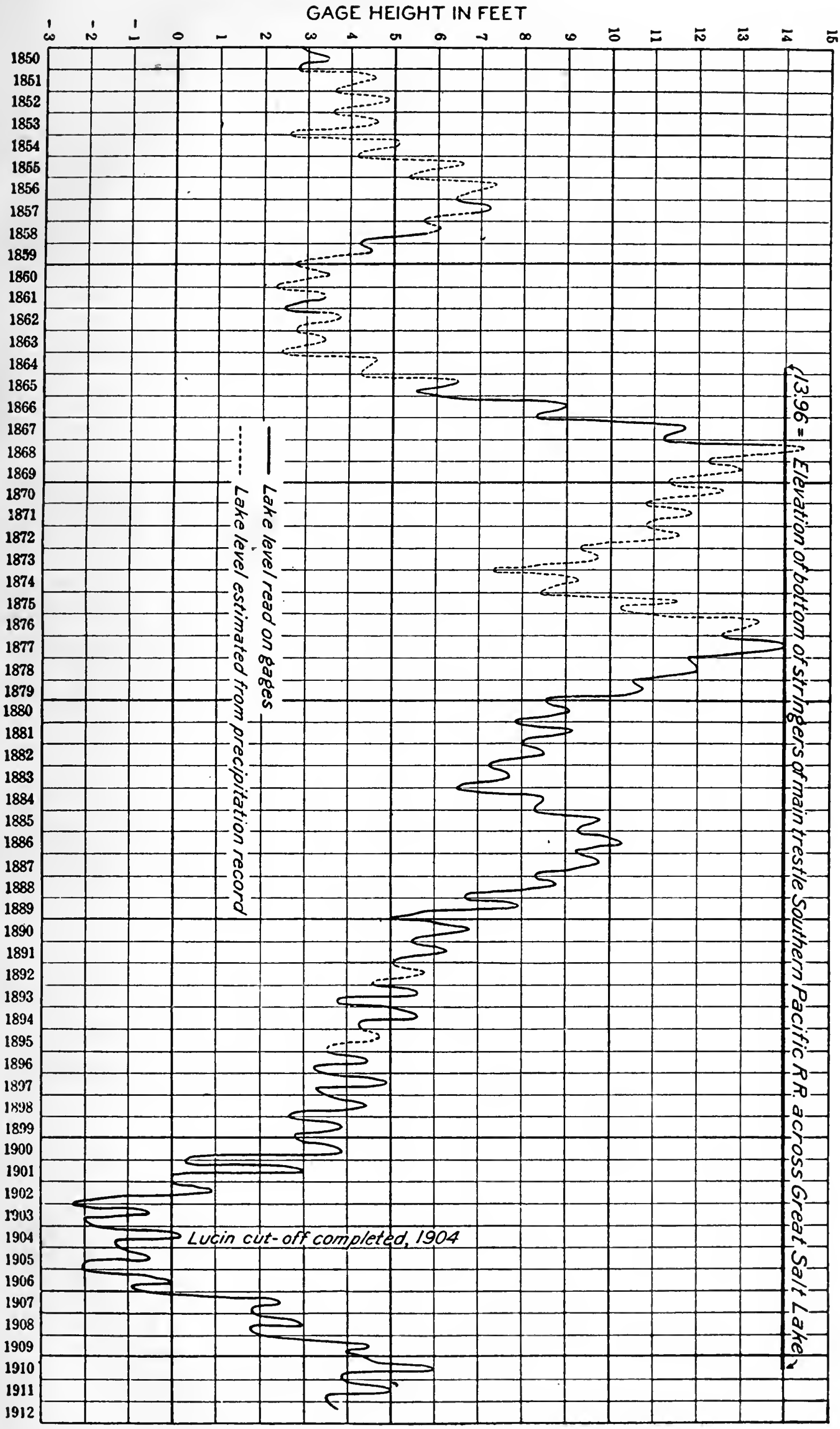

FIGURE 3.—Diagram showing fluctuations of water surface of Great Salt Lake, Utah, 1850-1911. By E. C. LaRue.

water surface has been kept in some form. E. C. LaRue [1] has compiled these data and plotted them in the diagram shown in figure 3 (p. 15), which gives a comprehensive idea of the fluctuations.

In describing the fluctuations, LaRue says:

During the years 1902 to 1905, feeling was general among the leading engineers of the West that Great Salt Lake was gradually drying up and that in a few years the lake would be replaced by a great salt desert. It is now very evident that this apprehension was unfounded. The accompanying diagram shows the actual lake levels for a period of 61 years, beginning with the year 1850. The lake level appears to rise and fall with a series of wet and dry years. The mean precipitation from 1886 to 1905 was 13.76 inches. The maximum precipitation during this period, 18.09 inches, occurred in 1891; the minimum, 9.37 inches, in 1887. The mean precipitation for the period 1906 to 1909, inclusive, was 20.97 inches, the maximum, 23.35 inches, occurring in 1909, and the minimum, 19.36 inches, in 1907. It is very evident that the gradual rise in the lake level from 1906 to 1910 was due to the high mean precipitation of 20.97 inches during this period. With the data available at present it would be impossible to determine to just what extent the diversion of the streams for irrigation has affected the lake levels. * * * The diagram shows that the lake level for April, 1910, was approximately 6 feet above the zero of the gage, and that for a period of 26 years beginning in 1865 the lake stood above 6 feet on the gage, reaching a maximum height of 14.5 feet in 1868. * * *

The Lucin cut-off was completed in 1904. The mean lake level was then approximately −0.5 foot. The bottom of the stringers of the main trestle over Great Salt Lake is 13.95 feet above the zero of the lake gage. The bottom of the stringers when the cut-off was constructed was therefore approximately 14½ feet above the lake level.

Although the Lucin cut-off has been damaged considerably by the rising of the lake, it will in all probability never be abandoned, for should the lake rise another foot or so, it will spread out over an immense flat and afford an enormously increased surface for evaporation, thereby checking the rise of the lake.

Owing to the extensive use of the water for irrigation within the Great Salt Lake drainage area, it is reasonable to believe that the lake will never rise above the 8-foot mark again, as it has been well below this stage since the year 1888.

CLIMATE.

TEMPERATURE.

The temperature of this region is not excessively high in summer nor excessively low in winter, but it varies daily through a wide range. The following table gives the summarized data in regard to the temperature and frosts:

Temperatures (° F.) in northwestern Utah.

Place.	Length of record.	January.			February.			March.		
		Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
	Years.									
Corinne	40	60	−16	26	67	−14	30	76	−5	39
Kelton	32	50	−14	23	58	−27	28	72	1	39
Government Creek	9	54	−14	28	63	−23	31	75	1	37

[1] LaRue, E. C., Eng. News, vol. 64, July, 1910, p. 261.

Temperatures (° F.) in northwestern Utah—Continued.

Place.	April.			May.			June.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
Corinne	89	16	50	97	23	59	105	29	68
Kelton	80	14	49	92	13	58	106	36	69
Government Creek	80	9	46	86	21	52	99	28	62

Place.	July.			August.			September.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
Corinne	109	38	77	110	31	70	101	23	61
Kelton	114	37	74	107	34	74	94	20	61
Government Creek	101	34	73	102	39	71	94	23	61

Place.	October.			November.			December.			Annual.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
Corinne	95	18	50	76	−6	37	59	−11	25	110	−16	50.5
Kelton	86	10	47	70	−1	34	61	−15	27	114	−27	49.2
Government Creek	83	17	49	68	−1	42	33	− 9	25	105	−22	48.8

Frost in northwestern Utah.

Place.	Length of record (years).	Average date of first killing frost in autumn.	Average date of last killing frost in spring.	Earliest date of killing frost in autumn.	Latest date of killing frost in spring.
Corinne	19	Oct. 4	May 16	Sept. 16	June 7.
Kelton	32	do	May 5	Sept. 9	May 17.
Government Creek	9	Sept. 30	May 24	Sept. 12	June 23.

PRECIPITATION.

RECORDS.

Rainfall observations have been made for a number of years at Corinne, Promontory, Kelton, Snowville, Tooele, and Government Creek, and more recently at Lucin, Grouse Creek, Midlake, and Iosepa. The following table summarizes the rainfall data of these stations.

Precipitation (in inches) in northwestern Utah.

Year.	Boxelder County.						Tooele County.		
	Promontory.	Kelton.	Corinne.	Lucin.	Grouse Creek.	Snowville.	Tooele.	Government Creek.	Iosepa.
1870									
1871	8.82		14.38						
1872	3.87		10.92						
1873	7.91		16.20						
1874			12.01						

Precipitation (in inches) in northwestern Utah—Continued.

Year.	Boxelder County.						Tooele County.		
	Promontory.	Kelton.	Corinne.	Lucin.	Grouse Creek.	Snowville.	Tooele.	Government Creek.	Iosepa.
1875									
1876			9.66						
1877	6.98		5.41						
1878	12.08		8.84						
1879	7.54	4.07	7.50						
1880	3.30	2.21	8.02						
1881	5.24	4.69	12.94						
1882	8.18	3.12	8.74						
1883	6.74	3.75	10.01						
1884	14.67	13.44	18.95						
1885	8.88		16.54						
1886	5.70	7.13	11.78						
1887		5.12	7.31						
1888		6.95	11.90						
1889	4.33	7.23	14.56						
1890	4.70	6.73	11.35						
1891	14.27	14.48	17.79			15.11			
1892	11.40	6.39	14.62						
1893	11.70	4.22	12.61			10.96			
1894	11.87	8.88	9.76			11.81			
1895	5.95	1.46	7.45			8.42			
1896	7.37	5.34	10.00			14.28			
1897	9.58		11.19			10.05	14.49		
1898	5.47	4.65	8.50			7.80	18.25		
1899	6.31	3.70	10.87			10.56	14.87		
1900	6.34	4.85	11.53			7.92	12.31		
1901	6.03	3.35	15.16			9.44	14.19	15.01	
1902	5.28	3.08	13.10			9.51	10.12	10.18	
1903		5.48	14.27			9.65	12.03	9.41	
1904	3.25	10.95	12.76			14.50	18.13	15.37	
1905		8.23	11.70			12.01	14.94	13.61	
1906		9.44	22.35			17.04	20.31	18.09	
1907		10.56	16.78			14.03	17.65	16.28	
1908	8.28	6.76	18.98			12.02	23.50	17.04	
1909	22.28	11.20	21.70	3.82			22.97	17.91	
1910	5.92	4.49	10.00	2.80			11.14	7.53	
1911	8.94	5.75	12.59	5.65	10.99		12.26	8.42	9.85
Mean.	8.25	6.37	12.50	4.09		9.80	15.74	11.53	

The average annual precipitation is 12.50 inches at Corinne, 8.25 inches at Promontory, 6.37 inches at Kelton, 11.47 inches at Snowville, and 4.09 inches at Lucin. These averages indicate a gradual westward decrease in precipitation (fig. 4). They are perhaps conclusive for the plains on which the stations are maintained, but they are not representative of the mountain areas. The luxuriant growth of timber on the Grouse Creek, Raft River, Black Pine, and Pilot Mountains indicate that considerable moisture is precipitated in the western parts of these counties, although at great altitudes.

ANNUAL VARIATION.

The rainfall at any given station varies from year to year within wide limits. The recorded range in annual precipitation is between 22.35 and 5.41 inches at Corinne, between 22.28 and 3.25 inches at Promontory, 14.48 and 2.21 inches at Kelton, 17.04 and 7.80 inches at Snowville, 23.50 and 10.12 inches at Tooele, and 18.09 and 7.53 inches at Government Creek. These variations are regional rather than local, there being in general an agreement between the curves of the different stations. Thus in 1884 and 1891 and in each year

from 1904 to 1908, inclusive, the precipitation was above the average at all stations where records were kept, and in 1879, 1880, 1882, 1883, 1887, 1895, and 1910 it was below the average at all stations. These annual variations are shown graphically in figure 5 (p. 20), which represents the rainfall by years since the installation of weather stations at the several points.

Heavy rains may, however, fall in one locality when it is dry at others. In 1908 the rainfall at Tooele was above the average, although at the other stations it was below the average.

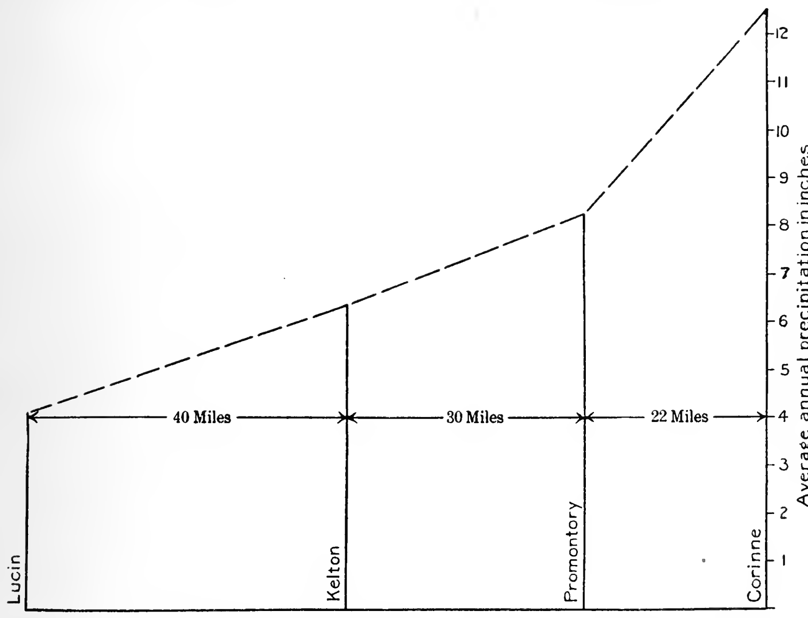

FIGURE 4.—Diagram showing decrease in precipitation in Boxelder County, Utah, from east to west.

SEASONAL VARIATION.

The average monthly rainfall is greatest in March, April, and May, and least in June, July, and August. The spring rains are in general heavier than those occurring in the fall. (See fig. 6, p. 21.)

Average monthly rainfall at nine stations in Boxelder and Tooele counties, Utah.

Station.	Length of record.	Years covered.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Years.													
Corinne	42	1870–1911	1.67	1.24	1.38	1.08	1.45	0.58	0.44	0.59	0.68	1.02	1.12	1.55
Promontory	42	1870–1911	.96	.95	.76	.71	.94	.20	.38	.69	.59	.65	.65	.94
Snowville	20	1890–1909	1.31	.87	1.61	1.14	1.52	.65	.37	.38	.50	1.02	.84	1.14
Kelton	34	1878–1911	.69	.64	.50	.66	.83	.39	.36	.22	.45	.45	.41	.74
Lucin	3	1909–1911	.69	.88	.04	.03	.26	.46	.05	.07	.23	.32	.31	.65
Grouse Creek	1	1911	1.99	.69	.33	.62	.86	2.17	.57	.00	1.40	.36	.68	1.03
Tooele	16	1896–1911	1.29	1.38	2.05	1.59	2.31	.70	.65	.96	1.04	1.25	1.45	1.02
Government Creek (James ranch)	12	1900–1911	1.17	1.44	2.14	1.27	1.41	.63	.57	1.19	.87	.47	1.17	.94
Iosepa	1	1911	1.23	1.21	1.40	.61	.68	.92	.57	.00	1.06	.96	.65	1.31

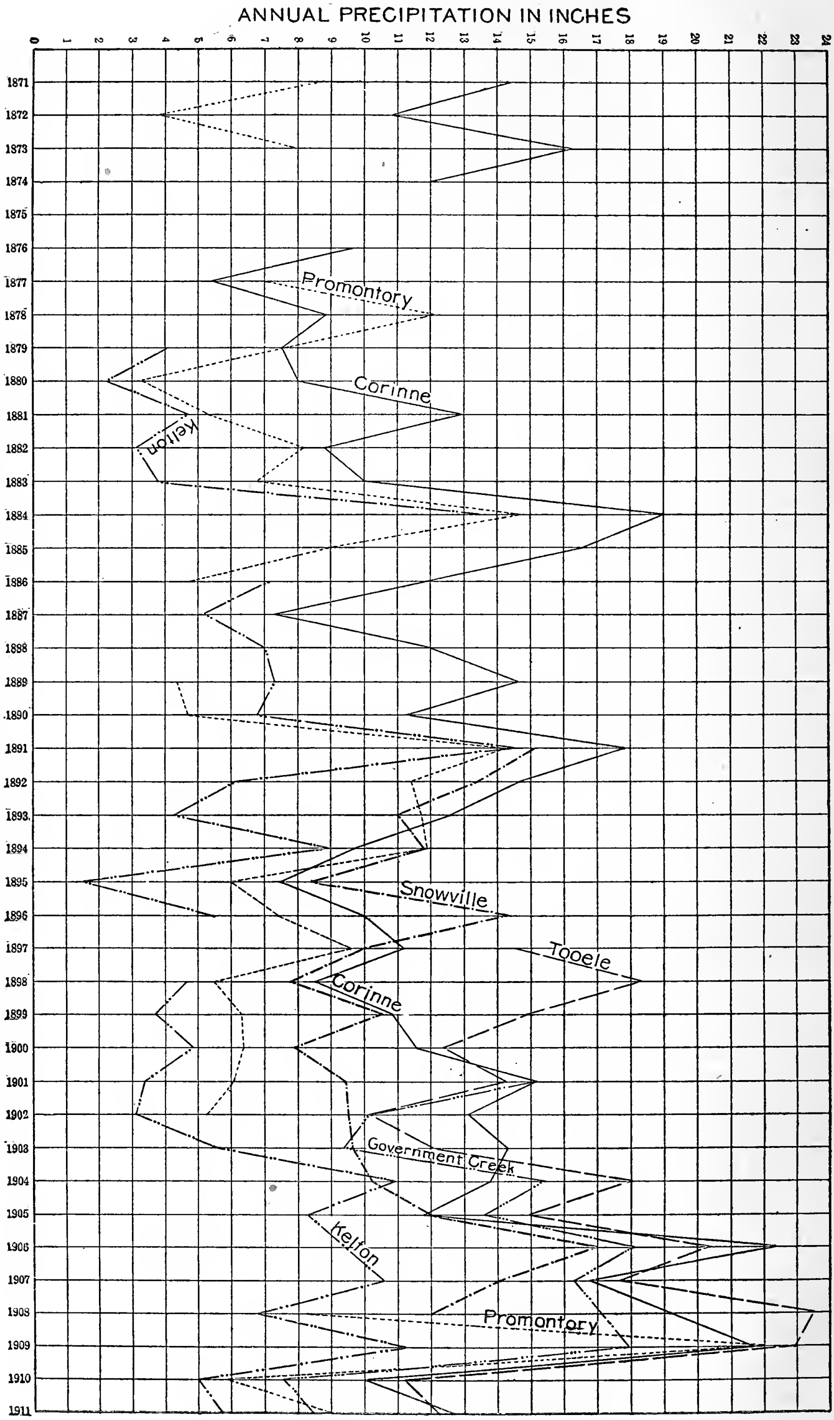

FIGURE 5.—Diagram showing annual precipitation at six stations in Boxelder and Tooele counties, Utah.

RELATION OF RAINFALL TO DRY FARMING.

In former years the farmers relied almost wholly on irrigation, but of late they have made extensive attempts to raise crops by dry-farm methods. More especially is this true in Curlew, Pocatello, Blue Spring, and Rush valleys, where dry farming has been undertaken on a large scale. These attempts have been fairly successful, but their success is proportional to the rainfall, which is in general greatest in the eastern part of the region and decreases westward. The records of the western stations are too short to warrant any definite statement as to the amount of rainfall in the western part or to suggest how far west dry farming can be made successful. The wet period, extending from 1904 to 1909, has been favorable to dry-farming operations, but considerable grain was also raised without irrigation in 1911, which appears to have been a year of nearly normal precipitation.

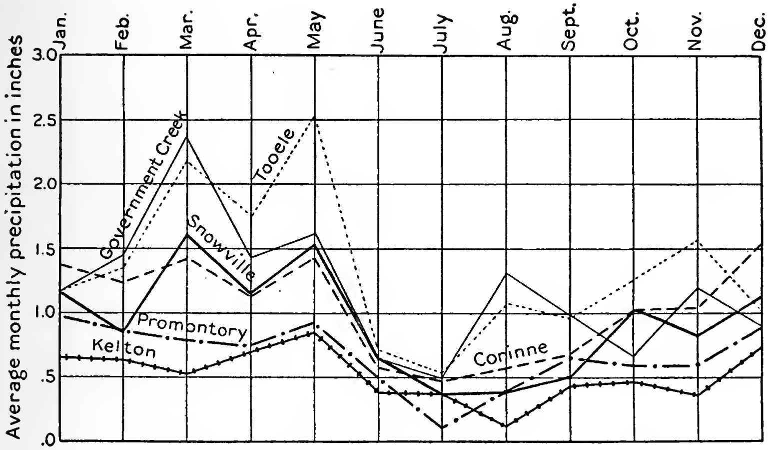

FIGURE 6.—Diagram showing average monthly precipitation at six stations in Boxelder and Tooele counties, Utah.

VEGETATION.

The vegetation of this region is not unlike that found in other parts of the Great Basin. In the relatively humid mountain areas junipers, pine, cedars, quaking aspen, and trees of other kinds are found, some of the mountains having timber of sufficient size to warrant their withdrawal for forest reserves. The valleys support a much less luxuriant growth and their dominant plants are of the drought-resistant or alkali-resistant types. The following species, determined by W. F. Wright, of the United States Department of Agriculture, are typical of this region: *Spirostachys occidentalis* (salt brush), *Sarcobatus vermiculatus* (greasewood), *Atriplex confertifolia* (shadscale), *Gutierrezia sarothræ* (match brush); *Chrysothamnus nauseosus* (rabbit brush), *Artemisia tridentata* (sagebrush).

The native plants of the valleys and plains grow in three distinct belts, determined with respect to the alkali and moisture content of the soil. The higher alluvial slopes, which receive the most rainfall and the greatest part of the run-off from the mountains and which contain the least alkali, support a heavy growth of sagebrush; the lower slopes, where the soil is drier and the alkali content is probably greater, yield a sparse growth of shadscale and match brush; and the low flats, which contain the greatest amount of alkali, either produce salt-resistant plants, such as greasewood and salt brush, or are entirely barren. Local conditions affect the general arrangement of these belts, so that heavy sagebrush may occur in places surrounded by shadscale, or vice versa.

SOIL.

Only a relatively small part of the land in Boxelder and Tooele counties is arable, the mountains, swamps, and alkali tracts being in general worthless for agriculture. Nevertheless there is in the aggregate a large acreage of good agricultural land—much larger than can be irrigated with the supply of water that is available or that would be available if all the water resources were fully developed and conserved. The best agricultural lands lie between the gravelly soils of the upper alluvial slopes and the clayey alkali soils of the flats.

The lowest tracts of the valleys almost everywhere contain alkali in harmful quantities. The surface waters flowing over the higher areas dissolve the soluble salts and carry them to the lower levels, where they are concentrated by evaporation; also the underground waters are near the surface in the low tracts and in some places are drawn up by capillary action and evaporated, leaving behind the salts that they contained. Through these processes the soluble substances of the upland regions have accumulated in the lower parts of the valleys until they are present in injurious amounts.

STREAMS.

Bear and Malad rivers are the largest streams that enter this region. The former rises in the lofty plateau east of this region and flows northward through Utah and southwestern Wyoming into southeastern Idaho, where it turns and flows back into Utah and empties into Great Salt Lake. Much of its water is used for irrigation before this region is reached, but a large amount is also diverted soon after the stream enters Boxelder County. Malad River rises in southern Idaho and flows into Utah, where it empties into Bear River. It is not an important source of irrigation waters in its lower course on account of salt springs which empty into it, but the tributaries near its head furnish water for considerable acreage of land.

Many small streams rise in the mountains and flow into the valleys, where they normally sink into the ground, but during the irrigation

season practically all the water from such streams is used long before it reaches the sinks. Among the streams of this class are Boxelder, Blue Spring, Deep, Indian, Dove, and Grouse creeks in Boxelder County, and Clover, Ophir, Vernon, North Willow, South Willow, Emigrant, Pine, and Soldier creeks in Tooele County.

INDUSTRIAL DEVELOPMENT.

The region now comprising the State of Utah was unknown before 1833 except from the indefinite reports of the traders and trappers who occasionally made expeditions into it. In that year Capt. Bonneville conducted an excursion to Great Salt Lake in the interest of fur traders and took notes that were later published by Washington Irving. In 1842 Capt. Frémont explored the Utah region, he and his party being the first white men to sail a boat on Great Salt Lake. In 1847 the Mormons settled at the present site of Salt Lake City, and two years later Capt. Stansbury made a comprehensive study of the lake and its environs. The rush to California opened a road through the country, but not until the completion of the Union Pacific and Central Pacific railroads in 1869 was communication with the outside world made easily.

With the settlement of this arid State came the adoption of irrigation. The water of the mountain streams and springs was led upon the parched but rich soil and the desert became dotted with productive oases, each supporting an agricultural community proportionate in size to the stream or spring by which it was sustained. In many of these communities development practically ceased when all the normal stream flow had been appropriated, but in recent years the limits of the desert are persistently being crowded back and more and more of the waste land is being reclaimed. This agricultural expansion is being accomplished by the construction of reservoirs to conserve the flood waters that formerly ran to waste, by the improvement of irrigation methods whereby the duty of the water is increased, by the application of dry-farming methods to large tracts that lie near the mountains and are favored with more rainfall than most of the desert, and to a small extent by the development of underground waters by means of artesian wells or pumping plants.

OCCURRENCE OF GROUND WATER.

BEDROCK.

The Paleozoic strata, which consist of quartzite, indurated limestone, schist, and slate, are exposed in all the mountain ranges and generally dip at steep angles. The quartzites and limestones are relatively impervious but contain cracks, fissures, and bedding planes that permit the passage of water; the schists and slates are so highly

impervious that they are of little or no value as water bearers. In most places the Paleozoic rocks are in positions which are very unfavorable for the recovery of such water as they may contain. As a rule the water that sinks into these rocks issues as mountain springs or is carried to such depths that its recovery is impracticable. Only a few successful wells have been sunk into Paleozoic rocks and but few attempts have been made to obtain water by drilling in these formations. The presence of water in them, however, is shown by the conditions at the Mercur mining camp,[1] where water was found on the top of a shale bed at the base of a thick limestone, and also by the well of the San Pedro, Los Angeles & Salt Lake Railroad at Toplif, which was drilled about 450 feet in sedimentary rocks lying beneath the unconsolidated sediments and which obtained a bountiful supply of water. The following log was furnished by the railroad company:

Log of railroad well at Toplif, Utah.

	Thickness.	Depth.
	Feet.	*Feet.*
Yellow clay	....	10
Yellow clay and gravel	10	20
Yellow clay and bowlders	106	126
Clay, gravel, and sand	78	204
Limestone fragments and clay	11	215
Limestone, broken	10	225
Limestone quartzite, solid	10	235
Limestone quartzite and yellow clay	40	275
Lime quartzite, honeycombed	38	313
Lime quartzite, solid	49	362
Lime quartzite, crevices	32	390
Lime quartzite, solid	3	393
Lime quartzite and porphyry	43	436
Lime quartzite	30	566
Lime quartzite and porphyry, water-bearing	19	585
Lime quartz; stratified, crevices filled with water	13	598
	....	654

Indurated rocks of probable Tertiary age, consisting of limestone, clay, sand, conglomerate, and lava, occur in Curlew, Park, and Grouse valleys and on the flank of the Wasatch Mountains. These beds are less steeply inclined and, with the exception of the lava, are softer than the Paleozoic strata. In Curlew Valley lava is the only Tertiary rock that has so far been found. It outcrops at several localities, is most abundant on the hills, and has been encountered in wells below the valley fill. The Baker well, in sec. 9, T. 2 N., R. 9 W., passed through 52 feet of hard lava, below which it obtained water. In Park Valley the Tertiary rocks, composed of clay, limestone, and conglomerate, are in most places covered by Quaternary wash, but they are exposed in a few localities and are encountered in well drilling. The Hirsche well, in sec. 2, T. 12 N., R. 14 W., passed through 200 feet of limestone, below which it obtained a small flow.

[1] Spurr, J. E., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1895, p. 423.

This dense limestone is not water-bearing, but appears to be underlain by porous sediments that contain water which may prove to be under sufficient pressure to rise to the surface. In Grouse Valley the Tertiary deposits are chiefly clays, fine sands, and conglomerates. They outcrop on the west slope of the Grouse Creek Mountains and dip gently toward the valley. No attempt has been made to exploit these deposits for water, but as a large amount of rain falls on the high Goose Creek Range it is possible that they are saturated and would furnish supplies to deep wells sunk in the valley.

For the region as a whole the indurated rocks are not important as water-bearing formations. Their chief value lies in their confining function in the basins which they form and which are partly filled with unconsolidated water-bearing sediments. They prevent the downward escape of the water that sinks into the valleys, and cause this water to accumulate in the unconsolidated beds. In this way the rock basins act as huge reservoirs, whose supplies of water can be drawn upon in the lowland areas, and are therefore of great economic value.

UNCONSOLIDATED SEDIMENTS.

The Quaternary streams and lake deposits that occupy the valleys and lie beneath the deserts of this region are classed under the general heading "unconsolidated sediments," in contrast with "bedrock," which is used in describing the older indurated sedimentary beds and the igneous rocks. Even the Quaternary deposits are, however, somewhat cemented, as is shown by the fact that the walls of most of the dug wells stand without casing, but they are much less firmly cemented than the older rocks.

The unconsolidated sediments have been derived from the surrounding mountains. Since the mountains came into existence the agents of weathering, such as water, wind, and frost, have been actively engaged in breaking up the older rocks and transporting them to the valleys, the work of transportation having been accomplished chiefly by the streams and torrential floods. Thus the deep canyons and serrated peaks were carved and the alluvial slopes and desert plains were built up.

A torrential stream confined to a narrow mountain canyon may flow so swiftly that it will transport not only sand and clay, but also pebbles and even large bowlders. Upon issuing from the mouth of the canyon the stream spreads over a wider area, its gradient is less, and its volume is diminished by seepage. Consequently its velocity and transporting power are greatly reduced and it deposits the coarser part of its load. It is because of this fact that very coarse material is found beneath the higher portions of the alluvial slopes and that finer sediments, such as clay and silt, predominate near the base of the slopes and on the desert flats.

The sorting of transported material by mountain streams is very imperfect. Succeeding floods differ greatly in magnitude. If a small freshet follows a heavy flood it will deposit fine materials where the heavy flood had dropped only coarse gravel, and will form a kind of matrix around the pebbles and bowlders of this gravel. As a result of the variation in the size of the floods the alluvial slopes are very irregular in composition.

A stream, moreover, does not build up all parts of its slope simultaneously. It takes its course over one part of the slope until, by aggradation, its channel is elevated above the other parts. Then the stream, always seeking the lowest levels, breaks away from the elevated tract and builds up another part of the slope. Consequently stream deposits have little continuity and wells sunk into them in close proximity may exhibit totally different sections.

When, however, a mountain torrent discharges into a body of quiet water, such as formerly existed in this region, the coarse material is dropped at the shore and only the finest material is carried out for any distance. This condition is found over most of Boxelder and Tooele counties. The map showing the area covered by Lake Bonneville (fig. 2, p. 13) indicates that all the valleys of this region were wholly or partly occupied by this ancient lake. The central flats are therefore composed largely of lake deposits of fine sand and clay that hold but little water and yield that little slowly. Especially is this true in broad valleys, such as lower Curlew Valley, and in the Great Salt Lake desert.

Coarse stream deposits are capable of absorbing and yielding large quantities of water. The rain that falls on the upper parts of the alluvial slopes and the mountain floods that are discharged over them sink quickly into the porous material, but the same cause that results in the rapid absorption of water may result in its rapid removal. The ground water, seeking a lower level, easily finds its way downward through such material to the central flats, and consequently wells sunk near the mountains may reach the water table only at great depths or may strike bedrock without finding water.

The unconsolidated sediments are the most important source of ground water, but they are not good water producers at every locality or horizon, the principal difficulties being (1) that they may be drained of their water, (2) that they may consist entirely of fine-grained material which does not permit the free passage of water, and (3) that the water may be salty.

SOURCE AND DISPOSAL OF GROUND WATER.

The annual increment to the water already stored in the ground is derived solely from the precipitation, but only a small part of the total rainfall reaches the water table. Much of the rain or snow

returns to the atmosphere by evaporation, either directly from the surface or after penetrating a short distance into the ground. Some of the moisture that falls on the mountains sinks into the rocks but reappears at lower levels in the form of springs and seepages, giving rise to small streams that may flow for some distance but are usually dissipated by evaporation and by sinking into the ground.

By far the greatest increment to the ground water is derived from floods. When there is a large amount of run-off from the mountains, because of heavy rains or melting snow, much water is discharged over the alluvial slopes and a part of it sinks into the loose material and descends to the water table. The underground supply thus augmented from time to time by contributions at the borders of a valley moves slowly toward the central flat, where through centuries the water level has risen until it is practically at the surface. On some of the valley flats and low deserts of northwestern Utah the ground water flows from springs and seeps or stands so high that it is brought to the surface by capillary action, the surplus in either case being disposed of ultimately by evaporation. The presence of springs, swamps, and alkali flats indicates that the water is near the surface and that evaporation is going on.

ARTESIAN CONDITIONS.

BEDROCK.

As a rule, conditions are unfavorable in this region for obtaining artesian water from bedrock. The strata in the mountain areas generally either dip away from the adjacent valleys or dip toward them so steeply that they carry the water to depths from which its recovery is impracticable. Ordinarily, too, the rocks are so broken by faulting and folding that they will not hold water under pressure.

Except at one well in Park Valley, no flows have been struck in bedrock, and, except possibly in this valley, there is no place in the region where conditions are sufficiently favorable to warrant the expense of trying to get artesian water.

UNCONSOLIDATED SEDIMENTS.

Artesian water has been found in the unconsolidated sediments at Willard and Kelton, on Dove Creek, near Rosette, in Boxelder County, and at Grantsville, Erda, and Vernon, in Tooele County. The fact that wells in these places have obtained flowing water has been a strong incentive for attempting to obtain flows in very unfavorable localities. For this reason the more fundamental conditions controlling artesian flows are here set forth.

The unconsolidated sediments in the valleys of northwestern Utah consist of gravel, clay, and fine sand. Beneath the alluvial slopes gravel predominates, but toward the central flats it gives way

to finer materials, consisting mainly of sand and clay in alternating layers. These beds of fine material are not entirely horizontal but conform to the general shape of the valleys, sloping from the central axis of a valley up toward the mountains. Clay is impervious, but sand and gravel are porous and allow the water to pass through them. The water that sinks into the gravel in the higher areas travels slowly toward the center of the valley, becomes confined below the curving clay beds, and accumulates back toward the mountains. The hydrostatic pressure thus produced may become so great that when the clay layers are punctured, as in drilling, the confined water will rise to the surface, forming flowing wells. (See fig. 7.)

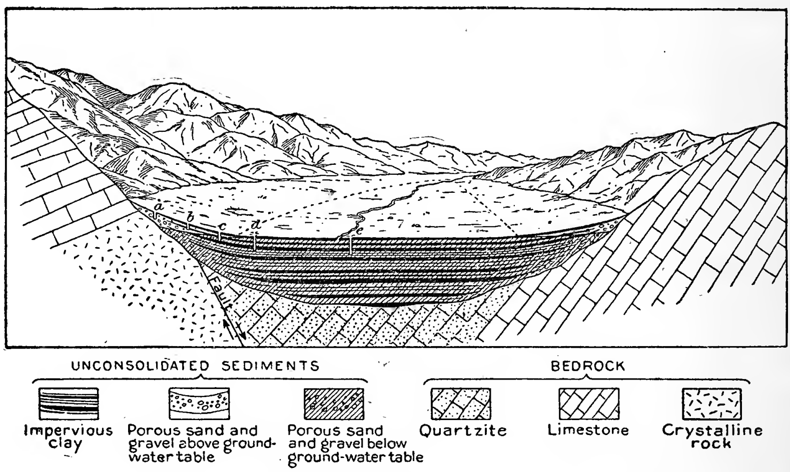

FIGURE 7.—Perspective view and diagrammatic cross section of a typical valley, showing relation of alluvial slopes and central flats to water table. *a*, Dry hole which if sunk deeper would strike bedrock without finding water; *b*, dry hole which would find water if sunk deeper; *c*, pump well of moderate depth; *d*, strong flowing well; *e*, weak flowing well. Dotted line represents base of alluvial slope.

If the clay layers were perfectly impervious the head of water would in many valleys be great enough to produce flows with strong pressure, but in fact they allow the water to penetrate them to such an extent that few of the flowing wells have a head of more than a few feet. For this reason springs, seeps, and alkali flats, which show that the ground water is under sufficient pressure to escape to the surface, are indicators of artesian conditions. A valley showing no overflow in the low places has poor prospects for flowing wells.

Large steep alluvial slopes and an abundant water supply from the mountains are also promising conditions for flows. Stronger wells are generally obtained nearer the base of the slopes than farther out on the flat, because the slight disadvantage in level is more than counterbalanced by the greater coarseness of the sand and gravel and the closer proximity to the supply.

Only a small part of the water now stored in the ground would flow out of wells without pumping, for a complete development of

the artesian basins would reduce the level of the water head. The amount that can be recovered from flowing wells in each year, though dependent on the annual increment, is probably indicated closely by the amount that escapes annually in low places by evaporation. This is far from being the unlimited supply that is often assumed for artesian basins.

More water could probably be recovered in each of the flowing well areas of this region. Wells intended to supply water for irrigation should be of large diameter and should be sunk through all the water-bearing strata of the unconsolidated sediments. The casings should be perforated at each level where flows were encountered, thus insuring the greatest possible discharge.

SPRINGS.

MOUNTAIN SPRINGS.

The springs of this region fall into two general classes—mountain springs and valley springs. The mountain springs include seepages and structural springs.

The water from snow or rain sinking into the disintegrated material that covers the mountainous areas in some places may percolate through this loose débris until it meets some outlying ledge of rock which brings it to the surface. These springs, which may be classed as seepages, usually have only a slight discharge and are very susceptible to differences in rainfall, being strongest during or shortly after a period of rainy weather and weakest during a period of drought. Many springs of this type occur in the mountains of northwestern Utah.

In contrast with the seepages are the structural springs, whose occurrence depends on the rock formations. The water from rain or melting snow may penetrate into the mountain rocks, following cracks and fissures or some porous strata until it meets an outcropping ledge, fault, or fissure which forces it to the surface, where it gushes forth as a structural spring. The discharge of such springs is more nearly uniform than that of seepage springs and constitutes an important part of the low-water flow of the permanent streams of this region.

VALLEY SPRINGS.

It has been explained that in most of the valleys and on the flat desert the sediments are saturated with water to the level of the lowest parts, and that as new supplies are added overflows occur in these low places. A large part of the overflow is accomplished by evaporation from minute pores in the ground, but a part is accomplished by the flow of water through larger openings in the ground, forming springs and seepages. Springs of this class commonly emerge

at the bases of high alluvial slopes that receive a copious water supply and are least abundant in the central flats. Seepage springs of a second class are found in the unconsolidated sediments where stream channels have been eroded, as along the channels of Malad and Bear rivers.

A third class of valley springs is represented in Park Valley. The unconsolidated deposits of this valley are underlain near the mountains by Tertiary beds, chiefly limestone, that outcrop in a few places. The water that sinks into the unconsolidated beds creeps along on top of the limestone until it is brought to the surface. Springs produced in this way are more like the mountain seepage springs than the ordinary seepage springs in the valleys. Most of the springs in Park Valley are of this class.

HOT SPRINGS.

Near the surface the temperature of the ground varies with the seasonal changes in the weather, but at certain depths the rocks and the water they contain are not affected by these changes but maintain a constant temperature, which is approximately the mean annual temperature of the region. At greater depths the rocks and water become gradually warmer, the increase being generally about 1° F. for each 50 to 100 feet of increase in depth. Where lava has been brought to the surface or injected into the rocks or where the strata have been subjected to deformation movements the increase in temperature is much more rapid. If the temperature of water that issues from a spring is higher than the mean annual temperature the spring is a thermal spring. The high temperatures indicate that the water comes from a deep source or from rocks that have been heated by volcanic activity or deformation, or possibly by some other agency.

This region contains a number of springs whose waters are distinctly above the normal. The principal ones are the hot springs at Hot Springs, at Honeyville, near Plymouth, and at the south end of Little Mountain. These are all in lower Bear River valley and all occur near fault lines in the Paleozoic strata. It seems probable that their waters come from great depths or from rocks that have been heated by deformation.

QUALITY OF GROUND WATER.

SUBSTANCES CONTAINED IN WATER.

The nearly pure water that falls as rain or snow takes up quantities of the soluble salts with which it comes into contact as it percolates through the earth, and therefore water from springs or wells always contains more or less mineral matter in solution. The mineral sub-

stances, which are invisible while dissolved, are left in solid form, when the water is evaporated, as the scale in boilers and teakettles or the white crust on alkali flats. The dissolved substances consist chiefly of calcium, magnesium, sodium, potassium, and the chloride, carbonate, bicarbonate, and sulphate radicles, but small amounts of other soluble substances are generally present.

METHOD OF ANALYSIS.

About 150 samples of water from northwestern Utah were tested by the methods described in Water-Supply Paper 151,[1] estimates being made of the chlorides, carbonates, bicarbonates, sulphates, and total hardness. Four samples thus tested were analyzed in the laboratory by J. R. Bailey of the University of Texas, as a check on the field work, with the results shown in the following table. The differences between the field and laboratory estimates are not great enough to prevent fair judgment of the general value and character of the waters by means of the results of the field assays. The normal carbonate reported in the laboratory analyses probably developed during transit by the decomposition of bicarbonates. In the table the first line opposite each sample represents the laboratory analysis and the second line the field assay.

Comparison of laboratory analyses and field assays of waters in northwestern Utah.

[Parts per million.]

No. of sample.	Depth of well.	Depth to water.	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Total hardness.	Chlorine (Cl).
	Feet.	*Feet.*								
10	....	....	36	18	6	13	162	12	163	8
			a 65	....	b 18	0	148	30	134	10
125	17	9	56	21	112	15	315	33	227	107
			a 85	....	b 97	0	381	30	214	147
131	....	....	83	39	216	10	205	44	367	429
			a 110	....	b 190	0	270	38	270	415
142	405	225	74	22	58	8	180	27	275	146
			a 80	....	b 143	0	263	30	204	175

a Calcium and magnesium (Ca+Mg) computed from the total hardness of field assays.
b Computed from the amounts of chlorine, bicarbonates, sulphates, and hardness.

10. Waterworks, Brigham. Water from Boxelder Creek.
125. Dug well of C. W. Goodliffe, Park Valley.
131. Waterworks, Snowville. Water from spring.
142. State drilled well, sec. 12, T. 13 N., R. 7 W.

The accuracy of the field assays has been discussed by Dole[2] who makes the following statement based on his work in San Joaquin Valley, Cal.:

> The average error in the test for bicarbonates was found to be a little over 6 parts per million, or 3.5 per cent, with waters containing 100 to 350 parts per million of

[1] Leighton, M. O., Field assay of water: Water-Supply Paper U. S. Geol. Survey No. 151, 1905.
[2] Dole, R. B., Rapid examination of water: Econ. Geology, vol. 6, No. 4, June, 1911, p. 340.

bicarbonates. The errors range from 0 to 9 per cent, and computation shows that they probably occur in measuring the water. * * *

The field results on low chlorines may vary from the true values 5 parts, but such discrepancy offers little practical disadvantage because it is as useful in reconnaissance to know that a water contains less than 10 parts of chlorines, for instance, as to know that it contains exactly 6.7 parts. The average error in waters containing more than 50 parts of chlorine was found to be 6 parts, or 3.2 per cent. * * * Twenty-seven of the fifty-two waters contained more than 30 parts of sulphates and the average error of determination in those was 10 per cent. Individual determinations of high sulphates are liable to great error because a difference of 1 cubic centimeter in measuring the water during dilution or a difference of 1 millimeter in measuring the turbidity is proportionately magnified in the result. The best depth for the readings is between 20 and 190 millimeters, corresponding respectively to 328 and 36 parts per million, and the probable error in that range is 8.5 per cent.

SUBSTANCES DISSOLVED IN WATERS OF NORTHWESTERN UTAH.

The ground waters of northwestern Utah are similar in composition to those of other arid regions. Most of those from the alluvial slopes contain less dissolved matter than those from the central part of the valleys and those from high valleys less than those in alkali flats. Chlorine is the most abundant element, the assays showing a maximum of about 27,000 parts per million in the waters tested. Normal carbonates are uncommon in most of the area, but in lower Bear River valley as much as 120 parts per million were found. Of the bicarbonates 735 parts per million were found, but this amount is much above the average. Sulphates ranged from a small amount to 690 parts, but the average was below 50. The highest total hardness recorded is 500 parts per million, and the waters in general are very hard. Those containing the greatest amount of dissolved matter are in lower Bear River valley, where the ground supply is influenced by irrigation.

RELATION OF DISSOLVED SUBSTANCES TO DOMESTIC USE.

To be entirely acceptable for domestic use water should be free from disease-producing organisms and low in dissolved mineral matter. The nearer these conditions are approached the better the water is for consumption. Most of the bacteria that water may contain are probably harmless, but some may produce typhoid fever or other diseases, and for this reason wells from which domestic supplies are to be obtained should be carefully located and shallow wells near stables and privies should be avoided. The danger is greatest where water is taken from streams or canals.

The amount of dissolved mineral substances permissible in domestic water depends much on their nature. No more than traces of barium, copper, zinc, or lead should be present, because these substances are poisonous. Iron is objectionable because it renders the

water unpalatable and causes stains on clothing and vessels. Hydrogen sulphide in large quantities is nauseating to smell and has a strong corrosive action on metal fittings.

According to Dole [1] 250 parts per million of chlorine is sufficient to make water taste "salty," and less amounts cause corrosion. MacDougal,[2] judging from experience in the desert, states that waters containing 2,500 parts per million of dissolved salts may be used for many days without serious discomfort; that those containing as much as 3,300 parts can be used only by hardened travelers; and that those containing 5,000 parts or more are inimical to health and comfort but might suffice for a few hours to save the life of a person who had been wholly without water. Stabler [3] found that in Carson Sink, Nevada, a water containing 1,300 parts per million of chlorine was used for drinking without apparent ill effect; and others containing 1,185 and 1,060 parts were considered by the users to be of good quality. The wide range between these estimates may be considered to represent the difference between the amount of salt perceptible to taste and the amount that can be tolerated if necessary.

Hardness of water is caused by calcium and magnesium, which form with soap an insoluble curdy precipitate, and it may be estimated from the results of a chemical analysis by means of the formula: Hardness $= 2.5$ calcium $+ 4.1$ magnesium.[4] The chief objection to hardness in water for domestic use is the increased consumption of soap which it causes.

Though about 400 parts per million of the sulphate radicle are perceptible to the taste, water containing much more may be used without serious effect. Stabler [3] reports that water containing 1,550 parts of sulphates was considered good by its consumers. This quantity might be objectionable because of the laxative effect of sulphates on persons unaccustomed to them.

The alkali carbonates are most objectionable where present in water in large quantities. Bicarbonates are not so injurious as normal carbonates, but they may be converted into the latter form by removal of carbon dioxide. That the quantity of alkali salts of this nature may be great without causing harmful effect is proved by the fact that the well-known Apollinaris water, which contains an equivalent of about 2,100 parts per million of sodium bicarbonate,[5] is used exclusively for drinking by many persons.

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[1] Dole, R. B., Chemical character of water of north-central Indiana, Water-Supply Paper U. S. Geol. Survey No. 254, 1910, p. 237.

[2] MacDougal, D. T., Botanical features of North American deserts: Pub. Carnegie Inst. Washington No. 99, 1908, p. 109.

[3] Stabler, Herman, unpublished data.

[4] Dole, R. B., Rapid examination of water: Econ. Geology, vol. 6, No. 4, June, 1911.

[5] Anderson, Winslow, Mineral springs and health resorts of California, San Francisco, 1892, p. 322.

RELATION OF DISSOLVED SUBSTANCES TO USE IN IRRIGATION.

SOURCE OF ALKALI.

The most common constituents of water that are injurious to plants are the sulphate, chloride, and carbonate of sodium. Sodium sulphate and sodium chloride are known to irrigators as "white alkali," from the fact that they appear as a white incrustation on the soil when the water containing them is evaporated. Sodium carbonate is commonly known as "black alkali," because it forms with the humus of the soil solutions a dark-colored compound that leaves black rings on the ground.

All soils and rocks contain the elements which in contact with water are formed into alkalies. In regions of copious rainfall the alkalies do not become abundant enough to be injurious to plants because they are washed away as fast as they are formed. In regions of deficient rainfall, however, the drainage is imperfect and allows most of the water to be evaporated in low places, consequently the soluble salts are deposited in the central flats, where they become concentrated in such amounts that plants are stunted or even killed. Thus alkali is not uniformly distributed over the surface of the ground or throughout the soil. The position at which it is likely to occur in dangerous quantities is on or very near the surface. Even there, however, it is more abundant on the central flats and in other depressions than on the higher alluvial slopes. It decreases in quantity with depth and seldom occurs in injurious amounts more than a few inches below the surface. The accumulation of alkali in some places is augmented by irrigation, for water thus applied may sink to a slight depth into the soil and later be brought by capillary action to the surface, where it deposits on evaporation not only the original salts which it held but the additional amounts which it has dissolved from the soil.

LIMITS OF ALKALI IN SOIL.

The amount of alkali that may be contained in soil in which crops can be grown successfully has been the subject of much investigation. Permissible amounts have been determined in some regions, but so many factors influence such estimates that the results are not applicable to regions that are widely separated. In the Dakotas, for instance, crops may be grown in soils with higher alkali content than in southern California, because of the quantity and distribution of the natural precipitation.

The report of the Bureau of Soils[1] in regard to the resistance of plants to alkali in lower Bear River valley says:

> Young wheat was found doing well with from 0.50 to 0.56 per cent of salt in the surface foot, and oats were growing not quite so favorably. Both crops, however, would apparently mature satisfactorily.

[1] Jensen, C. A. V., Strahorn, A. T., Soil survey of the Bear River area, Utah, 1904, pp. 28–30.

During the spring, when sugar beets were young, tests were made at the root crowns of beets that seemed to be growing in their limit of alkali, and the amount of soluble salt found in the first foot was 1.52 per cent. Late in the summer the same field was visited and borings were made in the same alkali spot, and it was found that beets were growing well and would mature in soil carrying from 2.50 per cent to 4.70 per cent in the surface foot, with 0.42 per cent to 0.84 per cent in the second foot.

In the early part of the season, when the beets were 4 or 5 inches high, it was found that 1.50 per cent of soluble salts in the first foot was about the maximum content that the beets could stand. Other plants were examined that were dying, but in no case was it found that any of these were growing in less than 1.50 per cent.

An interesting case of alfalfa growing in alkali soil was found in section 31, T. 10 N., R. 3 W. A heavy, well-matured crop was growing in soil containing the following percentages of salt from the first to the sixth foot, respectively: 0.14, 0.27, 0.43, 2.00, 3.12, and 3.75, an average of 1.62 per cent, and there was standing water at 4 feet.

An apple and peach orchard was found dying in section 1, T. 9 N., R. 3 W., where the salt content, in percentages, from the first to the sixth foot, respectively, was as follows: 0.09, 0.16, 0.39, 0.48, 0.69, and 0.86, an average of 0.44 per cent. Standing water was here at 4 feet below the surface, and this is not a good test as to the effect of alkali alone, as with the water table so near the surface it also would be likely to interfere with the proper development of the trees. It is quite probable that if the water table had been 2 or 3 feet lower the trees would have been able to stand the amount of alkali found.

Experiments were conducted in California to determine the quantities of the various forms of alkali that might be present in soils in which cultures grew and reached maturity. The following table,[1] compiled from the reports of these experiments, gives the maximum tolerances observed on crops that are grown in Utah. The several columns are independent of one another; the figure for total alkali is not the summation of the figures in the first three columns, but is based on independent data.

Highest amount of alkali in which plants were found unaffected.

[Quantities expressed in pounds per acre in 4 feet depth.]

	Sodium sulphate (Na_2SO_4).	Sodium carbonate (Na_2CO_3).	Sodium chloride (NaCl).	Total alkali.
Grapes	40,800	7,550	9,640	45,760
Pears	17,800	1,760	1,360	20,920
Apples	14,240	640	1,240	16,120
Peaches	9,600	680	1,000	11,280
Apricots	8,640	480	960	10,080
Mulberries	3,360	160	2,240	5,760
Alfalfa (young)	11,120	2,360	....	13,120
Alfalfa (old)	102,480	....	....	110,320
Sorghum	61,840	9,840	9,680	81,360
Sugar beets	52,640	4,000	10,240	59,840
Wheat	15,120	1,480	1,160	17,280
Barley	12,020	12,170	5,100	25,520
Rye	9,800	960	1,720	12,480
Celery	4,080	....	9,600	13,680

[1] Hilgard, E. W., Soils, New York, 1906, p. 467.

LIMITS OF ALKALI IN WATER.

Basing his figures on the foregoing data of Hilgard and others, Stabler [1] has deduced formulas for classifying waters with respect to their value for irrigation. The fundamental principle in his work is the determination of the alkali coefficient, which may be defined as the depth in inches of water which on evaporation would yield sufficient alkali to render a 4-foot layer of soil toxic to the most sensitive plants. Whether injury would actually result from the application of such a water depends on conditions outside of the quality of the water. The method of irrigation, the crops grown, the character of soil, and the drainage would all have an important bearing, but are conditions of which the analyst would know but little. Therefore, it should be clearly understood that the alkali coefficient gives no information in regard to those conditions. In computing the formulas sodium as Na_2CO_3 was regarded 10 times more toxic and in the form of NaCl 5 times more toxic than sodium as Na_2SO_4.

The alkali coefficient (k) may be calculated from the data of a water analysis by means of the following formulas:

1. When $Na-0.65Cl$ is zero or negative, $k=\frac{2040}{Cl}$.
2. When $Na-0.65Cl$ is positive but not greater than $0.48SO^4$,

$$k=\frac{6620}{Na+2.6Cl}.$$

3. When $Na-0.65Cl-0.48SO_4$ is positive, $k=\frac{662}{Na-0.32Cl-0.43SO_4}$.

In the absence of a determination of sodium and potassium Na may be estimated from the equation

$$Na=0.41HCO_3+0.83CO_3+0.71Cl+0.52SO_4-1.25Ca-2.06Mg.$$

If calcium and magnesium have not been determined, one-half the total hardness as $CaCO_3$ may be substituted for the last two terms of the preceding equation.

The following approximate classification, which is based on ordinary irrigation practice in the United States, indicates in a very general way the customary limitations in the use of waters having various alkali coefficients:

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[1] Stabler, Herman, Some stream waters of the western United States: Water-Supply Paper U. S. Geol. Survey No. 274, 1911, pp. 177–179.

Classification of irrigation waters.

Alkali coefficient.	Class.	Remarks.
More than 18	Good	Have been used successfully for many years without sepcial care to prevent alkali accumulation.
18 to 6	Fair	Special care to prevent gradual alkali accumulation has generally been found necessary except on loose soils with free drainage.
5.9 to 1.2	Poor	Care in selection of soils has been found to be imperative, and artificial drainage has frequently been found necessary.
Less than 1.2	Bad	Practically valueless for irrigation.

WATER SUPPLY BY AREAS.

MALAD AND LOWER BEAR RIVER VALLEYS.

TOPOGRAPHY.

The area between the Wasatch Mountains and the Blue Springs Hills is a single structural basin which received the drainage of two streams. (See Pl. I, in pocket.) Malad River rises in Idaho and flows south through the basin, and Bear River enters through a gap in the Wasatch Mountains near Collinston. The two rivers unite at Corinne and flow to Great Salt Lake. The area along Malad River north of Plymouth is regarded as Malad Valley and the area south of that point along Bear River as lower Bear River valley. The width of this basin is variable; lower Bear River valley in the vicinity of Corinne is about 18 miles wide, but it gradually narrows northward to the State line, where the distance between the Wasatch Mountains and the Blue Spring Hills is only 3½ miles.

The floor of these valleys, which rises gradually from the lake toward the north, is smooth and regular except near Bear and Malad rivers, which have intrenched themselves in the unconsolidated sediments, and in the vicinity of Little Mountain, which projects abruptly above the surface. After the recession of Lake Bonneville Bear and Malad rivers eroded their channels until they reached the limit of erosion. They are therefore deeply intrenched and flow in broad winding channels over the flood plains which they have built along their courses. North and east of Bear River Bay the land is low, swampy, and alkaline. The boundary of this tract on the east side of the bay practically coincides with the railroad, but north of the bay its boundary is very irregular. Alkali and swamp land extend along the Wasatch Mountains to Honeyville and along the Blue Spring Hills north of Little Mountain, but a tract of good farm land extends along Bear River nearly to the lake. North of this

alkaline and swampy tract the land is well drained and excellently adapted to agriculture. The mountains on either side rise abruptly, and the alluvial slopes along their borders are consequently high and steep, the central flat extending nearly from mountain to mountain. On the east the lofty Wasatch Mountains rise to an almost uniform height of about 9,000 feet above sea level except for a short distance near Collinston where they descend to form the pass leading to Cache Valley. Bear River has cut its way through the mountains at this place but not through the lowest part of the pass. On the west side of the valley the Blue Spring Hills rise to a height of about 7,000 feet above sea level, or from 2,000 to 3,000 feet above the level of Great Salt Lake.

GEOLOGY.

BEDROCK.

The indurated strata are confined to the mountainous areas. Those exposed in the Wasatch Mountains consist of limestones, quartzites, schists, and slates of Paleozoic [1] and Tertiary [2] age. In most places they dip to the east at a steep angle, but locally they are inclined in other directions. A great fault occurs at the foot of these mountains, the rocks on the east side of the fault being raised with respect to those on the west and a complete section of the Paleozoic rocks being exposed.

The Blue Springs Hills are variously tilted and folded, but in general they take the form of a broad syncline, the strata on both sides of the hills being exposed by faulting. The age of the rocks in these hills has not been definitely determined, but they resemble the Carboniferous rocks in other parts of the region.

Little Mountain, which projects through the unconsolidated sediments west of Corinne and covers an area of about 7 square miles, is composed of beds of indurated limestone and quartzite that dip about 20° N.

UNCONSOLIDATED SEDIMENTS.

The unconsolidated sediments, which are composed of fragmental material derived from the adjoining mountains, have been referred to the Pleistocene series by Gilbert and others. No deep wells have been sunk in this basin, and the depth to which these unconsolidated sediments extend has not been determined, but well borings in the vicinity of Farmington (see p. 11) show that in that locality they are more than 2,000 feet thick. The following section of strata exposed on the banks of Bear River near Deweyville is typical of the material encountered in the shallow wells of the central flat.

[1] Hague, Arnold, Rept. U. S. Geol. Expl. 40th Par., vol 2, p. 403; also Blackwelder, Eliot, New light on the geology of the Wasatch Mountains, Utah: Bull. Geol. Soc. America, vol. 21, 1910, pp. 517-542.

[2] From fossils collected by the writer.

Section of unconsolidated sediments near Deweyville, Utah.

	Feet.
Soil	5
Sand and clay	4
Red clay	6
Sandy clay	12+
	27+

SURFACE WATER.

STREAMS.

Malad and lower Bear River valleys receive the drainage of approximately 6,500 square miles. Bear River, the largest stream, rises on the north slope of the Uinta Mountains in the northeastern part of Utah, and after a circuitous course, in which it enters Wyoming, reenters Utah, appears again in Wyoming, and makes a long detour in Idaho, it returns to Utah through Cache Valley, breaks through the Wasatch Mountains near Collinston, and makes its way to Great Salt Lake. It drains an area of 6,000 square miles above the gap at Collinston, and furnishes water for irrigating large tracts of land. A gaging station has been maintained since 1889 near Collinston below the intake of the irrigation canals. In 1907, after a year of excessive rainfall, the run-off amounted to 2,680,000 acre-feet, and in 1890, 1894, 1897, 1899, and 1909 it was also in excess of 2,000,000 acre-feet. In 1895, the driest year at Corinne recorded by the Weather Bureau during this period, the run-off was only 701,000 acre-feet.

Malad River, whose drainage area comprises only about 500 square miles, is an unimportant source of water for irrigation in these valleys on account of the poor quality of its water. In its upper course, however, the water is extensively used. No measurements have been made of its discharge.

Boxelder and Willard creeks rise in the Wasatch Mountains near Brigham and are second in importance to Bear and Malad rivers as sources of irrigation water. Their drainage areas are small, probably together covering little more than one township. The discharge of Boxelder Creek averages about 24 second-feet,[1] but fluctuates considerably throughout the year, being least in summer and greatest in spring.

QUALITY OF SURFACE WATER.

The surface waters examined from these valleys are of fair quality for domestic use and entirely suitable for irrigation. Two analyses have been made of water from Bear River, one sample being taken from the canal and the other from the river at Corinne. These analyses were made at different times and are therefore not strictly comparable,

[1] Jensen, C. A., and Strahorn, A. T., Soil survey of the Bear River area, Utah: Seventh Rept. Field Operations Bur. Soils, U. S. Dept. Agr., 1905, p. 23.

but the great differences which they show are doubtless largely due to an increase of mineral matter toward the mouth of the stream. Such increase is caused partly by the return seepage of the water applied in irrigation, which carries the salts from the soil into the river, and partly by the water of Malad River, which empties into Bear River above Corinne. The water of Boxelder Creek is low in dissolved solids and is good for every purpose, as is shown by the analysis in the following table. The first two analyses, reported in grains per gallon in hypothetical combinations, have been recalculated to ionic form in parts per million in order that they may be comparable with other analyses in this report.

Analyses of stream water from Malad and lower Bear River valleys.

[Parts per million.]

	Location.	Source.	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Total hardness as $CaCO_3$[a].	Chlorine (Cl).
1	Northwest corner sec. 1, T. 11 N., R. 3 W.	Canal	54	27	57	11	254	40	245	56
2	Corinne	Bear River	64	30	130	[b] 137	....	52	285	206
3	Brigham	Boxelder Creek.	36	18	6	13	162	12	165	8

	Dissolved solids.	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.	Quality for boiler use.	Quality for domestic use.	Alkali coefficient (k).	Quality for irrigation.	Mineral content.	Chemical character.
							In.			
1	499	270	150	N. C.	Poor	Fair	30	Good	Moderate	Na—CO_3
2	637	310	350	...do	Bad	Poor	16	Fair	High	Na—Cl
3	220	190	15	..(?)	Good	Good	25	Good	Moderate.	Ca—CO_3

[a] Computed by formula T. H. = 2.5 Ca + 4.1 Mg.
[b] Carbonates and bicarbonates computed as CO_3.
1. Utah-Idaho Sugar Co., owner. Jensen, C. A., and Strahorn, A. T., Soil survey of Bear River area, Utah, Seventh Rept. Field Operations Bur. Soils, U. S. Dept. Agr., 1905, p. 22.
2. Analysis by Southern Pacific Co.
3. Analysis by J. R. Bailey, Austin, Tex.

The relative proportions of the mineral constituents in the water of Great Salt Lake remain nearly the same, but their concentration varies with changes in the lake level. The average salinity is always several times greater than that of sea water, being nearly 20 per cent, or 200,000 parts per million. The following analyses and the discussion of them are quoted from Clarke.[1]

[1] Clarke, F. W., The data of geochemistry, 2d ed.: Bull. U. S. Geol. Survey No. 491, 1911, pp. 143, 144.

Analyses of water from Great Salt Lake

[Percentage of anhydrous residue.]

	1	2	3	4	5	6	7	8
Cl	55.99	56.21	55.57	56.54	55.69	55.25	55.11	53.72
Br	Trace.	....	....	....	Trace.	Trace.	....	....
SO_4	6.57	6.89	6.86	5.97	6.52	6.73	6.66	5.95
CO_3	....	.07	....	....	....	....	....	....
Li	Trace.	....	....	....	.01	Trace.	....	....
Na	33.15	33.45	33.17	33.39	32.92	34.65	32.97	32.81
K	1.60	(?)	1.59	1.08	1.70	2.64	3.13	4.99
Ca	.17	.20	.21	.42	1.05	.16	.17	.31
Mg	2.52	3.18	2.60	2.60	2.10	.57	1.96	2.22
Fe_2O_3, Al_2O_3, SiO_2	....	....	....	....	.01	....	....	....
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Salinity (total solids) per cent of total water	14.994	13.790	15.671	19.558	[a]23.036	27.72	22.99	17.68

[a] More correctly, 230.355 grams per liter.

1. By O. D. Allen, Rept. U. S. Geol. Expl. 40th Par., vol. 2, 1877, p. 433. Water collected in 1869. A trace of boric acid is also reported in addition to the substances named in the table. Allen also gives analyses of a saline soil from a mud flat near Great Salt Lake. It contained 16.40 per cent of soluble matter much like that of the lake water.

2. By Charles Smart. Cited in Resources and attractions of the Territory of Utah, Omaha, 1879. Analysis made in 1877.

3. By E. von Cochenhausen, for C. Ochsenius, Zeitschr. Deutsch. geol. Gesell., vol. 34, 1882, p. 359. Sample collected by Ochsenius April 16, 1879. Ochsenius also gives an analysis of the salt manufactured from the water of Great Salt Lake.

4. By J. E. Talmage, Science, vol. 14, 1889, p. 445. Collected in 1889. An analysis of a sample taken in 1885 is also given.

5. By E. Waller, School of Mines Quart., vol. 14, 1892, p. 57. A trace of boric acid is also reported.

6. By W. Blum. Collected in 1904. Recalculated to 100 per cent. Reported by Talmage in Scottish Geog. Mag., vol. 20, 1904, p. 424. An earlier paper by Talmage on the lake is in the same journal, vol. 17, 1901, p. 617.

7. By W. C. Ebaugh and K. Williams, Chem. Zeitung, vol. 32, 1908, p. 409. Collected in October, 1907.

8. By W. Macfarlane, Science, vol. 32, 1910, p. 568. Collected in February, 1910. A number of other analyses, complete or incomplete, are cited in this paper by Ebaugh and Macfarlane.

The absence of carbonates, the higher sodium, and the lower magnesium are the most definite variations from the oceanic standard; but the general similarity, the identity of type, is unmistakable. Gilbert estimates the quantity of sodium chloride contained in the lake at about 400 millions and the sulphate at 30 millions of tons.

IRRIGATION WITH SURFACE WATER.

The most important factor in the irrigation of lower Bear River valley is the canal system owned by the Utah-Idaho Sugar Co. This system, which diverts water from Bear River 2 miles above the electric power plant, was begun in the late eighties, but was not brought to its present efficiency until a much later date. About 45,000 acres are irrigated at present and it is estimated by the company that 10,000 acres more can be watered with the present supply. About 1,300 second-feet are diverted from the river at the intake of the canals, but several hundred second-feet are returned to the river in generating electric power. It appears that at present about 65 acres are irrigated per second-foot of water.

GROUND WATER.

SPRINGS.

Seepage springs emerge along the foot of the slopes bordering the Wasatch Mountains and have been of great importance in the development of these valleys. They are present between Brigham and Deweyville and between Plymouth and the State line in great numbers. Springs of the same type but saline in character are found at the south end of the Blue Spring Hills and the Little Mountains, but thermal springs are present at Hotspring station, near Honeyville and Plymouth, and at the south end of Little Mountain. These springs have temperatures ranging from 96° to 140° F., all but one being above 118° F. Analyses of three of these springs are given in the following table:

Analyses of water from Hot Springs in lower Bear River valley, Utah.

[Parts per million. Analyst, J. R. Bailey.]

Location.	Owner.	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Dissolved solids.
South end of Little Mountain.	W. F. House..	2	878	379	10,426	0.0	393	20	18,460	30,440
Hot Springs.....	Hot Springs Sanitarium.	9	1,174	28	8,563	.0	188	203	15,079	25,300
Honeyville......	James Madsen.	1	901	218	16,559	.0	454	497	27,081	45,541

ARTESIAN WELLS.

Flowing wells are found along the base of the alluvial slope near Willard. Their position is due without doubt to the fact that the slopes in this part of the valley receive a more bountiful supply of water than the slopes farther north. The flowing wells are 125 to 150 feet deep and probably are all supplied from beds of sand and gravel in the valley fill. Nearly all are 2 inches or less in diameter and their natural flow is but a few gallons a minute.

NONFLOWING WELLS.

Nonflowing wells are obtained throughout lower Bear River valley at very shallow depths, the irrigation system having raised the water table almost to the surface. Most of the wells sunk in the central flat find water at depths of 3 to 10 feet, and as a result of the high altitudes at which the canals have been placed, the wells sunk in the alluvial slopes also usually find water at shallow depths. The water table has thus been artificially raised, and in some places the nearness of the water to the surface greatly hampers farming operations. In Malad Valley, north of the irrigated districts, the average depth to

the water table is somewhat greater, but even in this valley the central flat is close to the water table. In the vicinity of Plymouth and northward to the State line water is found in less quantities at depths ranging from 10 to 135 feet. Plate I (in pocket) shows the depth at which the water stood in the wells in the summer of 1911.

QUALITY OF THE GROUND WATER.

The table on pages 45–49 gives the results of 104 assays of water from wells and springs in Malad and lower Bear River valleys. Carbonates, bicarbonates, sulphates, chlorine, and total hardness were estimated in accordance with standard methods of field assay. (See p. 31.) The total amount of calcium and magnesium in each water has been roughly approximated from the total hardness and the quantity of alkali (sodium and potassium) has been calculated by means of the formula on page 36. Consequently both figures should be regarded as expressing estimates and should not be too literally interpreted, as they serve merely to show in a general way the nature and amount of the bases.

The alkali coefficients have been computed in accordance with the formulas given on page 36, and the waters have been rated with respect to their availability for irrigation by Stabler's classification. Almost all supplies are poor for irrigation and many contain so much mineral matter as to be unfit for that purpose. It is apparent from the results of the assays that even the best of the waters could be applied only to soils that have been thoroughly underdrained and with great precaution to prevent undue accumulation of alkali, such as frequent irrigation with large quantities of water. Altogether the prospect of using these ground waters on crops does not seem encouraging.

The designation "quality for domestic use" refers exclusively to the probable effect of the mineral ingredients on potability and has no relation whatever to the possibility of pollution or the danger of contracting disease by the use of infected supplies. The rating is based generally on the tolerance of the human system for dissolved mineral matter and on the quantities that render supplies disagreeable to taste. Though nearly all the waters are high enough in their content of mineral matter to have a distinct taste of alkali, a large proportion of them are drinkable.

The supplies have been rated in respect to their quality for boiler use by means of formulas and classifications described by Dole.[1] The approximate amount of scale that would be deposited is estimated from the total hardness and the tendency to foam from the estimated quantity of alkalies. The symbol N. C. indicates that corrosion would

[1] Dole, R.B., Rapid examination of water in geologic surveys of water resources: Econ. Geology, vol. 6, 1911, p. 340.

probably not occur because of the mineral ingredients; C., that corrosion would be likely to occur; and an interrogation mark, uncertainty as to corrosive action. Most of the waters contain rather moderate quantities of scale-forming matter, but are especially high in the alkali salts that would cause foaming. It would hardly be advisable to remove the scale-forming ingredients by softening, as the foaming ingredients would thereby be increased. The tendency to foam is so marked that nearly all the supplies would be generally considered bad for boiler use.

Briefly, the assays show that these supplies are alkali waters of high mineral content, generally so high in foaming constituents as to be bad for use in boilers, and so concentrated as to be usable for irrigation only where extreme precautions are observed to prevent the accumulation of alkali. Most of them are drinkable, though many would have a taste of alkali.

Assays of ground water from Malad and lower Bear River valleys, Utah.

[Parts per million.]

Number of sample.	Owner.	Location.	Depth of well.	Depth to water.	Calcium and magnesium (Ca+Mg).[a]	Sodium and potassium (Na+K).[b]	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total dissolved solids.[c]	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.	Quality for boiler use.	Quality for domestic use.	Alkali coefficient.	Quality for irrigation.	Mineral content.	Chemical character.
			Feet.	Feet.														In.			
1		T. 25 N., R. 2 W.	90	60	55		52	0		25	135										
4	C. M. Clay		100	0	55		15	115		Tr.	135										
5	Harvey Woodyatt		100	0	50		15	65		205	80										
7		Sec. 15, T. 8 N., R. 2 W.	125	0	45		15	105		20	110										
8	George May	SW. cor. sec. 23, T. 10 N., R. 2 W.	17	11	40		0	260		65	100										
9	Joseph Yates	NW. cor. sec. 36, T. 10 N., R. 2 W.	22	17	75		0	370		175	190										
10	Brigham Water Works, Brigham, Utah.	Boxelder Creek			55		0	160		10	134										
11	L. A. Snow		11	8	55		0	170		25	135										
12	W. M. Core				40		0	235		20	105										
13	Albert Burt	SW. cor. sec. 8, T. 10 N., R. 2 W.	10	5	100		25	495		0	270										
14	Horace Petersen	Center of SW. ¼ sec. 12, T. 10 N., R. 3 W.	10	5	150		0	820		0	380										
15	O. S. Jensen	SW. cor. sec. 7, T. 10 N., R. 2 W.			110		0	435		430	295										
16	M. P. Jensen	NW. ¼ sec. 18, T. 10 N., R. 2 W.			140		0	630		90	270										
17	....do	NW. ¼ sec. 19, T. 10 N., R. 2 W.	28	10	70		0	315		435	175										
18	George R. Chase	NW. ¼ sec. 9, T. 9 N., R. 2 W.	10	7	90	360	0	335	40	130	220	600	250	970	N. C.	Bad	Fair	2.2	Poor	High	Na—CO_3
19	—— Buckley	NW. ¼ sec. 1, T. 9 N., R. 3 W.		0	90	760	110	660	215	290	230	1,600	260	2,100	...do	...do	Poor	1.0	Bad	...do	Na—CO_3
20		E. ¼ cor. sec. 2, T. 9 N., R. 3 W.			90	480	0	375	65	250	220	870	250	1,300	...do	...do	Fair	2.3	Poor	...do	Na—Cl
21	N. C. Hansen	Center of sec. 2, T. 9 N., R. 3 W.	7	3	25	590	60	495	60	395	65	1,300	90	1,600	...do	...do	Poor	2.0	...do	...do	Na—CO_3
22	Peter Pash	SW. cor. sec. 35, T. 10 N., R. 3 W.	8	3	70	940	95	990	210	380	170	2,000	200	2,500	...do	...do	...do	1.0	Bad	...do	Na—CO_3

[a] Approximated from total hardness.

[b] Computed by means of formula on p. 36.

[c] Computed from the estimates of the acid radicles.

Assays of ground water from Malad and lower Bear River valleys, Utah—Continued.

Number of sample.	Owner.	Location.	Depth of well.	Depth to water.	Calcium and magnesium (Ca+Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total dissolved solids.	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.	Quality for boiler use.	Quality for domestic use.	Alkali coefficient.	Quality for irrigation.	Mineral content.	Chemical character.
			Feet.	*Feet.*														*In.*			
23	Cramer & Goodman.	NE. cor. sec. 10, T. 9 N., R. 3 W.	7	3	55	500	60	445	35	245	135	1,500	160	1,400	N. C.	Bad..	Poor.	1.0	Bad..	High.	$Na-CO_3$
24	Leo Jensen........	SW. cor. NW. ¼ sec. 15, T. 9 N., R. 3 W.	14	12	85	590	120	335	40	190	210	1,000	240	1,600	...do..	...do..	...do..	1.0	...do..	...do..	$Na-CO_3$
25	Mrs. H. L. Steed...	Center sec. 22, T. 9 N., R. 3 W.	6	5	100	310	0	300	30	80	245	450	280	810	C.....	...do..	Fair..	2.0	Poor.	Moderate.	$Na-CO_3$
26	—— Frederickson.	NE. cor. sec. 31, T. 9 N., R. 3 W.	10	Driven.	75	800	65	275	35	745	190	1,600	220	2,100	N. C.	...do..	Poor.	1.0	Bad..	High.	Na—Cl
27	J. Stearns.........	NE. cor. sec. 4, T. 9 N., R. 3 W.	7	4	160	1,650	0	340	110	1,750	290	3,300	320	4,400	...do..	...do..	Bad..	0	...do..	Very high.	Na—Cl
28	T. G. Brown......	SE. cor. SW. ¼ sec. 33, T. 10 N., R. 3 W.	6	3	65	650	30	435	95	445	160	1,300	190	1,700	...do..	...do..	Poor.	1.0	...do..	High.	Na—Cl
29	S. Owen..........	SW. ¼ sec. 32, T. 10 N., R. 3 W.	9	4	95	470	30	395	40	220	240	760	270	1,200	...do..	...do..	...do..	1.7	Poor.	...do..	$Na-CO_3$
30	W. D. Hill........	SE. ¼ sec. 32, T. 10 N., R. 3 W.	9	7	90	490	30	395	85	200	220	820	250	1,300	...do..	...do..	...do..	1.7	....	...do..	$Na-CO_3$
31	Public well.......	NE. cor. sec. 32, T. 10 N., R. 3 W.	.....	4	75	310	20	300	95	24	190	470	220	840	...do..	...do..	Good.	2.5	Poor.	Moderate.	$Na-CO_3$
32	H. C. House.......	S. ½ sec. 30, T. 10 N., R. 3 W..	6	3	5	220	18	275	50	60	15	360	40	590	...do..	Fair..	...do..	3.6	...do..	...do..	$Na-CO_3$
35	——— Pierce......	SW. ¼ sec. 28, T. 11 N., R. 4 W.	.....	20	130	630	0	355	100	295	320	970	350	1,700	C.....	Bad..	...do..	1.3	...do..	High.	Na—Cl
36	C. J. Peters.......	S. ½ sec. 2, T. 11 N., R. 4 W...	32	28	85	630	0	540	330	190	215	1,300	240	1,700	N. C.	...do..	Poor.	2.8	...do..	...do..	$Na-SO_4$
37	Thomas Laws....	NW. ¼ sec. 15, T. 11 N., R. 4 W.	66	60	105	520	0	295	275	200	265	1,000	300	1,400	(?)	...do..	Fair..	2.2	...do..	...do..	$Na-SO_4$
38	R. C. Harris.......	NW. cor. sec. 12, T. 11 N., R. 4 W.	.....	......	125	530	0	335	40	300	320	870	350	1,400	(?)	...do..	...do..	2.7	...do..	...do..	Na—Cl
39	L. H. Getz........	SE. cor. SW. ¼ sec. 1, T. 11 N., R. 4 W.	12	Driven.	185	830	0	330	670	185	465	1,800	500	2,200	(?)	Unfit	...do..	2.3	...do..	...do..	$Na-SO_4$
40	Philip Getz.......	SE. cor. sec. 12, T. 11 N., R. 4 W.	9	5	90	470	0	370	70	250	225	830	260	1,300	N. C..	Bad..	...do..	6.0	Fair..	...do..	Na—Cl
41	John Enthurm....	NW. cor. sec. 17, T. 11 N., R. 3 W.	9	5	105	930	0	395	220	750	270	1,900	300	2,500	...do.	...do..	Poor.	1.1	Bad..	...do..	Na—Cl
42	G. Rector.........	NW. ¼ sec. 8, T. 11 N., R. 3 W.	8	4	70	670	0	590	330	250	180	1,400	210	1,800	N. C.	Bad..	Poor.	2.9	Poor.	High.	$Na-SO_4$

44	A. A. Nichols	NW. cor. SE. ¼ sec. 36, T. 12 N., R. 4 W.	112	72	60	720	0	150	320	600	150	1,600	180	1,900	(?)	Bad	Poor	1.9	Poor	High.	Na—Cl
45	Saml. Enthurm	NE. cor. sec. 17, T. 11 N., R. 3 W.	.....	4	90	1,270	0	495	780	800	225	2,900	260	3,400	N. C	Bad	Fair	.9	Bad	High.	Na—Cl
47	G. L. Swerdfiger	W. ½ sec 3, T. 10 N., R. 3 W.	12	5	90	400	0	370	40	170	225	700	260	1,100	N. C	Bad	Fair	1.5	Poor	High.	Na—CO_3
48	Hansen Livestock Co.	SW. ¼ sec. 8, T. 10 N., R. 3 W.	14	10	200	1,180	0	265	50	1,200	405	2,200	440	3,200	(?)	Bad	Poor	.9	Bad	High.	Na—Cl
49	.....	E. ½ sec. 34, T. 11 N., R. 3 W.	.....	.....	120	980	0	340	575	565	310	2,100	340	2,600	(?)	Bad	Poor	1.2	Bad	High.	Na—SO_4
50	A. L. Benney	NE. cor. SE. ¼ sec. 16, T. 11 N., R. 3 W.	.....	3	55	430	0	485	80	175	135	750	180	1,200	N. C	Bad	Poor	2.0	Poor	High.	Na—CO_3
51	Albert Hardy	SE. cor. sec. 4, T. 11 N., R. 3 W.	11	5	55	680	0	800	180	300	135	1,400	180	1,800	N. C	Bad	Bad	1.3	Poor	High.	Na—CO_3
52	J. M. Haws	NE. cor. sec. 11, T. 11 N., R. 3 W.	16	8	85	390	0	58	210	220	215	740	240	1,000	C	Bad	Fair	2.9	Poor	High.	Na—Cl
53	Orsen Jensen	SW. cor. sec. 7, T. 11 N., R. 2 W.	10	6	55	520	0	450	120	300	135	1,100	160	1,400	N. C	Bad	Poor	2.4	Poor	High.	Na—Cl
54	.....	SW. cor. sec. 26, T. 11 N., R. 3 W.	.....	.....	65	700	0	315	170	735	160	1,700	190	1,900	N. C	Bad	Poor	1.8	Poor	High.	Na—Cl
55	Antone Christensen.	NW. cor. sec. 1, T. 10 N., R. 3 W.	6	5	75	470	0	485	100	185	185	900	220	1,300	N. C	Bad	Fair	1.8	Poor	High.	Na—CO_3
56	David Holngren	SW. cor. SE. ¼ sec. 13, T. 10 N., R. 3 W.	.....	6	65	860	0	465	330	600	160	1,900	190	2,300	N. C	Bad	Poor	1.2	Bad	High.	Na—Cl
57	E. M. Iverson	SW. cor. NE. ¼ sec. 2, T. 10 N., R. 3 W.	9	6	45	430	0	425	35	250	120	850	150	1,100	N. C	Bad	Fair	1.8	Poor	High.	Na—Cl
58	Knudsen Bros	NW. ¼ sec. 5, T. 10 N., R. 2 W.	11	9	55	350	0	20	0	400	135	700	160	940	C	Bad	Fair	3.0	Poor	High.	Na—Cl
59	Bear River Milling Co.	SE. cor. sec. 31, T. 10 N., R. 2 W.	15	12	65	350	0	455	35	100	160	600	190	940	N. C	Bad	Poor	2.2	Poor	High.	Na—CO_3
60	Thomas Wheatley	E. ½ sec. 9, T. 10 N., R. 2 W.	45	25	55	460	0	455	35	280	135	930	160	1,200	N. C	Bad	Poor	1.8	Poor	High.	Na—Cl
61	William Huntsinger.	NE. cor. NE. ¼ sec. 8, T. 10 N., R. 2 W.	9	6	65	400	0	460	40	300	160	960	190	1,100	N. C	Bad	Poor	2.3	Poor	High.	Na—Cl
62	E. C. Carr	NW. cor. sec. 32, T. 11 N., R. 2 W.	12	9	70	240	0	295	0	60	170	380	200	650	N. C	Bad	Fair	4.1	Poor	Moderate.	Na—CO_3
63	Andrew Madsen	SE. cor. sec. 20, T. 11 N., R. 2 W.	39	35	65	330	0	255	35	190	160	800	190	890	N. C	Bad	Fair	2.7	Poor	High.	Na—Cl
64	Jerome Marble	NE. cor. sec. 20, T. 11 N., R. 2 W.	35	5	65	390	0	525	85	75	160	750	190	1,000	N. C	Bad	Poor	2.1	Poor	High.	Na—CO_3
65	.....	NE. cor. sec. 6, T. 11 N., R. 2 W.	20	17	30	620	0	490	490	200	80	1,500	110	1,600	N. C	Bad	Poor	1.9	Poor	High.	Na—CO_3
66	E. O. Wight	NE. cor. NW. ¼ sec. 1, T. 11 N., R. 3 W.	16	12	55	660	0	465	185	445	135	1,400	160	1,800	N. C	Bad	Poor	1.5	Poor	High.	Na—Cl
67	.....	NW. cor. SE. ¼ sec. 1, T. 11 N., R. 2 W.	.....	.....	75	340	0	390	50	90	190	670	220	920	N. C	Bad	Fair	2.7	Poor	High.	Na—CO_3
68	J. J. Dewey	Center sec. 8, T. 11 N., R. 2 W.	12	6	65	270	0	345	(a)	55	160	340	1,200	730	N. C	Bad	Fair	3.3	Poor	Moderate.	Na—CO_3
70	W. M. Beaton	SW. cor. sec. 30, T. 12 N., R. 2 W.	.....	17	65	440	0	550	105	125	160	910	190	1,200	N. C	Bad	Fair	2.0	Poor	High.	Na—CO_3
72	W. S. Hansen	SE. cor. NW. ¼ sec. 7, T. 12 N., R. 2 W.	27	6	75	590	0	525	245	225	190	1,000	220	1,600	N. C	Bad	Poor	2.0	Poor	High.	Na—CO_3
73	Roy Peck	NE. cor. sec. 2, T. 12 N., R. 3 W.	.....	.....	60	250	0	245	45	85	145	440	170	660	N. C	Bad	Fair	3.1	Poor	Moderate.	Na—CO_3

a Less than 30.

Assays of ground water from Malad and lower Bear River valleys, Utah—Continued.

Number of sample.	Owner.	Location.	Depth of well.	Depth to water.	Calcium and magnesium (Ca+Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total dissolved solids.	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.	Quality for boiler use.	Quality for domestic use.	Alkali coefficient.	Quality for irrigation.	Mineral content.	Chemical character.
			Feet.	*Feet.*														*In.*			
74	E. M. Harris	NW. cor. NE. ¼ sec. 6, T. 12 N., R. 2 W.	8	4	55	250	0	325	(*a*)	60	135	450	160	660	N. C.	Bad	Fair	2.0	Poor	Moderate.	Na—CO_3
75	do	Center NE. ¼ sec. 29, T. 13 N., R. 2 W.	20	15 }	45	450	0	650	110	120	115	950	130	1,200	N. C.	Bad	Poor	1.8	Poor	High.	Na—CO_3
76	William Potter	SW. ¼ sec. 35, T. 13 N., R. 3 W.	.....	20 }	45	180	0	260	(*a*)	25	110	220	40	490	N. C.	Bad	Fair	4.0	Poor	Moderate.	Na—CO_3
77	William Bowkett	N. center sec. 20, T. 12 N., R. 2 W.	22	18	45	270	0	390	(*a*)	60	115	490	140	130	N. C.	Bad	Fair	2.7	Poor	Moderate.	Na—CO_3
78	John Standing	S. ½ NW. ¼ sec. 17, T. 12 N., R. 2 W.	30	10	20	470	0	470	145	260	50	1,100	80	1,200	N. C.	Bad	Poor	2.0	Poor	High.	Na—Cl
79	J. H. Shank	Center sec. 9, T. 12 N., R. 2 W.	33	6	40	330	0	390	110	105	95	700	120	890	N. C.	Bad	Fair	2.6	Poor	High.	Na—CO_3
80		NE. cor. sec. 32, T. 13 N., R. 2 W.	11	8	50	300	0	390	(*a*)	100	125	550	150	810	N. C.	Bad	Fair	2.5	Poor	High.	Na—CO_3
81		NE. cor. sec. 30, T. 13 N., R. 2 W.	28	10	40	330	0	260	135	150	95	700	120	890	N. C.	Bad	Fair	3.0	Poor	High.	Na—Cl
82		SE. cor. sec. 19, T. 13 N., R. 2 W.	.....	.....	55	350	0	360	100	160	135	770	160	950	N. C.	Bad	Fair	2.6	Poor	High.	Na—CO_3
83	Chas. F. Hess	NW. ¼ sec. 20, T. 13 N., R. 2 W.	35	12	60	270	0	390	(*a*)	40	155	480	180	730	N. C.	Bad	Fair	2.6	Poor	Moderate.	Na—CO_3
84	Joseph Josephson	NW. ¼ SW. ¼ sec. 7, T. 13 N., R. 2 W.	21	10	85	890	0	650	40	695	215	1,800	240	2,400	N. C.	Bad	Poor	1.0	Bad	High.	Na—Cl
85	Thos. Udy	SE. cor. sec. 15, T. 13 N., R. 3 W.	38	34	40	730	0	390	845	155	95	1,800	120	2,000	N. C.	Bad	Fair	2.1	Poor	High.	Na—CO_3
86	W. A. Hess	N. ½ NE. ¼ sec. 24, T. 13 N., R. 3 W.	34	29	60	370	0	390	135	95	155	740	180	1,000	N. C.	Bad	Fair	2.2	Poor	High.	Na—CO_3
87		NW. cor. sec. 17, T. 12 N., R. 2 W.	32	12	90	.....	.....	.....	110	120	230	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
88	Jesse Mason	N. ½ SW. ¼ sec. 8, T. 13 N., R. 3 W.	12	9	55	.....	.....	.....	175	80	135	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
89	E. S. Hansen	SW. cor. sec. 17, T. 12 N., R. 2 W.	18	10	55	.....	.....	.....	(*a*)	80	135	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
90	W. A. Rhodes	SW. cor. SE. ¼ sec. 25, T. 12 N., R. 3 W.	35	25	25	.....	.....	.....	150	100	60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

91	—— Ward	NE. ¼ sec. 35, T. 12 N., R. 2 W.			25				115	190	60										
92	George Clark	NW. ¼ SW. ¼ sec. 32, T. 12 N., R. 3 W.	16		70				40	120	175										
94	Park Bros.	SW. cor. NW. ¼ sec. 22, T. 13 N., R. 3 W.	135		55				0	225	140										
95		SE. cor. sec. 10, T. 13 N., R. 3 W.			70				(a)	80	170										
96	Hiram Esteps	S. ½ sec. 4, T. 13 N., R. 3 W.		50	45				67	140	115										
98	Joseph Tinns	NE. ¼ sec. 27, T. 14 N., R. 3 W.	13	9	60				(a)	40	155										
99	W. Vahn	N. ½ NE. ¼ sec. 22, T. 14 N., R. 2 W.	25	19	45				(a)	30	115										
100	Joseph Allen	N. ½ sec. 15, T. 14 N., R. 3 W.	15	14	45				(a)	40	115										
101	George M. Ward	Washakie	18	12	50				65	150	120										
102					60				(a)	150	155										
103					50				(a)	30	125										
104	Mary McCreary	Portage	53	51	70	560	0	290	265	325	175	1,200	200	1,500	N. C.	Bad.	Fair.	1.9	Poor.	High.	Na—Cl
105	T. P. Johns		140	32	70	260	0	290	55	50	175	450	200	700	N. C.	Fair.	Good.	11	Fair.	Moderate.	$Na—CO_3$

a Less than 30.

PUMPING TESTS.

In September, 1912, six pumping tests were made at Brigham, the data from which are given in the following table:

Pumping tests at Brigham.

Owner.	Location.	Depth of well.	Depth to water.	Diameter of well.	Total lift.	Cost of well and machinery.	Kind of pump.	Yield of well.	Method of determining yield.	Size of motor (horse-power).	Acres irrigated.	Cost of power per month.
		Feet.	*Feet.*	*Feet.*	*Feet.*			*Sec.-ft.*				
Fred Hansen	Brigham	55	46	8	48	$1,250.00	Horizontal shaft centrifugal, Byron Jackson.	0.1		10	14	$17.60
Joe Valentine	do	65	55	6	56.5	1,700.00	American	.9	Weir			19.40
Carl Isaacson	do	46	40	6		950.00	Vanway	.3	Estimated	10	4½	9.20
John Bott & Son	1 mile northeast of post office, Brigham.	40	38	8	60	1,110.00	Worthington	.6	do	15	35	21.00
Richards & Anderson	Brigham		24		29.9		Vanway	.5	Weir	7	7	10.80
Chas. Cheals	do	40	37.5	6	38.7	575.00	Byron Jackson	.3	do	5	5	8.50

The power for operating the pumps is obtained from the municipal electric lighting plant and costs a flat rate of $2 per horsepower per month.

IRRIGATION.

Over a large part of lower Bear River valley ground water is at shallow depths, but the land on which it is found is already well irrigated with surface water. Near Brigham and Willard, where fruit is the principal crop and where power is cheap, water can be lifted a greater distance than at other places. Less water is needed for an orchard than for most field crops, and the value of the fruit permits a greater cost in irrigating. In this locality the discharge from Boxelder and Willard creeks can perhaps be made to do double duty by using the stream water on the higher parts of the alluvial slopes and pumping the underflow on the lower land where the water level is nearer the surface than it is close to the mountains.

In Malad Valley and adjacent parts of lower Bear River valley the water table is in many places shallow enough to permit pumping for irrigation, but there is probably not sufficient water available to irrigate large areas. At Plymouth, although water for general irrigation can probably not be obtained, it is thought that sufficient water can be developed by pumping to irrigate gardens and orchards. Wells of large diameter should be dug to the first water-bearing strata, and smaller holes should be drilled in the bottom of these wells to the deeper water-bearing beds. The water that is found in the lower strata is generally under sufficient pressure to rise to the level of the first water.

BLUE SPRING AND POCATELLO VALLEYS.

TOPOGRAPHY AND GEOLOGY.

Blue Spring and Pocatello valleys are bounded on the east by the Blue Spring Hills, which have been described in connection with lower Bear and Malad River valleys (p. 37), and on the west by the Promontory Range, which separates them from Hansel and Curlew valleys. (See Pl. I, in pocket.) The Promontory Range is about 70 miles long and from 1 to 10 miles wide. Its highest peaks reach an elevation of about 7,000 feet above sea level, but in a few places the range descends to form low passes. The geology of the north end of Promontory Range has not been studied, but at the south end limestone, quartzite, schist,[1] and slate, ranging in age from pre-Cambrian to Carboniferous, are found. The strata dip to the west at a low angle, but are exposed on both sides of the range by faults.

[1] Hague, Arnold, Rept. U. S. Geol. Expl. 40th Par., vol. 2, 1877, pp. 420-429.

The area between these two mountain ranges is a structural trough separated into two drainage basins by a divide near the Utah-Idaho State line. Pocatello Valley occupies the area north of the divide and Blue Spring Valley the area south of it. At Kolmar station, on the old line of the Southern Pacific Railroad, the two ranges come almost together and form a highland through which Blue Spring Creek has cut a canyon. A belt of lowland extends southward from this station along the west side of Bear River Bay to Promontory Point.

Pocatello Valley is an almost flat-bottomed basin. It is about 12 miles long and 7 miles wide and has but slight alluvial slopes. During wet periods the water collects over about 2 square miles in the central flat, but there is no other surface water in the valley. According to the well records, the unconsolidated sediments are mostly red clay and extend to a depth of more than 500 feet.

The vertical range between the north end of Blue Spring Valley and Great Salt Lake is about 1,000 feet. This valley has high alluvial slopes, and the valley fill is coarser than that in Pocatello Valley. A few isolated bedrock hills project through the unconsolidated sediments, notably in the southern part. The largest one is just east of Howell; two others at the south end of the swampy tract below this settlement appear to form an underground dam across the valley which checks the underflow and produces a swamp. The area between the railroad and lake is alkaline and swampy and unfit for agriculture, but the land on the alluvial slopes west of the swampy tract and the bay is well adapted to farming and will perhaps be developed into a center for the fruit industry.

During the Pleistocene epoch, when Lake Bonneville occupied this part of Boxelder County, the south end of the Blue Spring Hills, the Promontory Range south of the old line of the railroad, and the large hill west of Kolmar were islands and the remaining portions of the mountains bordering on these valleys were peninsulas. The divide that separates the trough into two drainage basins was at or very near the surface of the water and formed a barrier to the action of waves set in motion by the south winds. The waters in Pocatello Valley were thus much quieter than those in Blue Spring Valley, and the shore features were consequently less distinctly carved. The character of the sediments also indicates that the waters in the northern part of the trough were less disturbed than those in the southern part. In the former red clay comprises most of the valley fill, but in the latter sand and gravel are abundant.

DEVELOPMENT.

For a time after the settlement of this portion of Utah the lands in these valleys were used only for grazing, but since the develop-

ment of dry-farming methods and the passage of the enlarged-homestead act they have been rapidly settled and now give promise of becoming an important grain-producing region. Houses have been built and wells sunk, and every attempt has been made to make these valleys suitable for habitation. Pocatello Valley, which has been settled longest, already produces valuable crops of wheat and barley, and Blue Spring Valley, although less developed, will doubtless also yield good crops.

SPRINGS AND STREAMS.

Blue Spring Creek, which rises at the spring of that name, is the only stream in either of these valleys. It formerly flowed into Great Salt Lake but is now diverted for irrigation. The Promontory Curlew Land Co. has recently constructed a reservoir on this stream (sec. 6, T. 12 N., R. 5 W.), from which about 3,000 acres of land are to be irrigated by utilizing the water of these springs and the flood water that formerly ran to waste. Hillside Spring, southeast of Howell, forms a part of the supply for that settlement. There is one small spring at the base of the slope southeast of Bond, Idaho, in Pocatello Valley, and the water from another spring has been piped from the mountains to Bond for domestic supply.

Along the foot of the slope bordering the Promontory Range south of Kolmar station seepage springs exist in great number. Some are potable and are used for irrigation, but most of them are too salty and are on land that is too low and swampy to be farmed. The Southern Pacific Co. has obtained an abundant supply for locomotives at Promontory Point by driving a 1,400-foot tunnel into the mountain in sec. 15, T. 6. N., R. 5 W.

GROUND WATER.

In Pocatello Valley the water table lies some distance below the surface. The wells range in depth from 165 to 500 feet, but the depth at which the water stands in most of the wells was not ascertained. In some of the wells the water is reported to have risen 150 feet, but in others it rose only a few feet above the water-bearing strata. The wells are all drilled and cased, the casing commonly being 4 inches in diameter. So far as could be determined the wells all end in the unconsolidated sediments, the strata encountered in drilling being chiefly red clay and gravel. Most of the wells in Pocatello Valley furnish enough water for farm use, but one or two yield only a few barrels a day.

Near the south end of Blue Spring Valley the water table is near the surface, but toward the mountains and toward the north end it becomes deeper. The water table has the same general shape as the

land surface, but it rises toward the mountains and the upper end of the valley less rapidly than the surface. Most of the wells are drilled, but a few are dug in the vicinity of Howell, where the water is found nearer the surface. One or two of the wells in the north end of Blue Spring Valley have encountered lava, but this fact should not be discouraging as water may be found in crevices in the lava or in gravel beds beneath it. Most of the wells furnish an abundant supply of water for house and stock use, but the supply in a few is small.

QUALITY OF WATER.

In the nine samples assayed from these valleys the average content of chlorine is 295 parts per million. Hardness ranged from 160 to 240, bicarbonates from 215 to 530, and sulphates from less than 30 to 275. The waters are generally poor for use in boilers, numbers 150 to 157 needing treatment for scale-forming ingredients and numbers 150, 152, 154, 158, and 159 being rather high in foaming ingredients. The wells in Blue Spring Valley yield water that is fair for domestic supplies and for irrigation, but those examined in Pocatello Valley are poor. The waters are somewhat salty and generally high in mineral content.

Assays of water in Pocatello and Blue Spring valleys.

[Parts per million.]

No. of sample.	Owner.	Location.	Source.	Depth of well.	Depth to water.	Calcium and magnesium (Ca+Mg).	Sodium and potassium (Na+K).	Total hardness as ($CaCO_3$).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total dissolved solids.[a]	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.	Quality for boiler use.	Quality for domestic use.	Alkali coefficient (k).	Quality for irrigation.	Mineral content.	Chemical character.
				Ft.	Ft.														In.			
150	Mr. Marsh	Center SE. ¼ sec. 23, T. 10 N., R. 5 W.	Spring	....	....	80	1,250	205	0.0	285	75	1,685	3,100	235	3,300	N. C.	Very bad	Poor	1.0	Bad	Very high.	Na—Cl
151	J. L. Baxter	NE. cor. NW. ¼ sec. 19, T. 12 N., R. 5 W.	Dug well	66	51	80	200	205	.0	215	40	275	690	235	540	?	Bad	Fair	7.4	Fair	High	Na—Cl
152	Howell town site well.	Howell, Utah	...do	92	....	80	160	205	.0	310	40	155	570	235	430	N. C.	...do	...do	7.4	...do	...do	Na—Cl
154	Louis Grant	NW. ¼ sec. 29, T. 13 N., R. 5 W.	Blue Springs.	....	....	75	630	185	.0	240	40	840	1,600	215	1,700	...do	Very bad	Poor.	1.9	Poor	...do	Na—Cl
155	Fred Manning	NW. cor. sec. 28, T. 13 N., R. 5 W.	Dug well	183	40	95	180	240	.0	240	(b)	405	900	270	485	?	Bad	Fair	1.9	Good.	...do	Na—Cl
156	W. W. Roskelly.	SW. ¼ sec. 18, T. 13 N., R. 5 W.	...do	113	53	80	110	205	.0	215	100	105	480	235	295	?	Fair	Good.	1.7	Fair	Moderate.	Na—CO_3
157	Louis Miller	SE. cor. sec. 8, T. 13 N., R. 5 W.	...do	180	80	80	180	205	.0	220	40	275	700	235	485	?	Poor	Fair	9.5	...do	High	Na—Cl
158	Joseph Peterson.	SW. ¼ sec. 4, T. 16 S., R. 34 E., Boise meridian.	Drilled well.	420	180	70	440	175	.0	530	275	230	1,230	200	1,200	N. C.	Bad	Poor.	2.7	Poor	...do	Na—SO_4
159	Emery Mitton	Center SW. ¼ sec. 3, T. 15 S., R. 34 E., Boise meridian.	...do	295	250	65	500	160	.0	480	105	475	1,300	190	1,350	...do	...do	..do	2.2	..do	...do	Na—Cl

a Calculated.

b Less than 30.

IRRIGATION WITH GROUND WATER.

In Pocatello Valley the water is too deep and the supply too small to be used for irrigation except possibly for gardens. Over most of Blue Spring Valley the ground water is also too deep to be utilized for irrigation except near the south end, where it may be found feasible to draw upon the ground water for irrigation supply. On the lower parts of the slope bordering the Promontory Range south of Kolmar station few wells have been sunk, but water is likely to be found at shallow depths and can probably be developed for irrigation. In order to ascertain the water supply it will be necessary to drill wells to a depth of a few hundred feet, being careful to tap any water beds that are penetrated and to test these wells by protracted pumping with large pumps. To be permanently successful a project must not draw from the underground reservoir at a rate more rapid than that at which the supply is replenished by nature, and for this reason extensive pumping developments should be made with great caution.

HANSEL VALLEY.

PHYSIOGRAPHY.

Hansel Valley is bounded on the east by the Promontory Range and on the west by the Hansel Mountains and Great Salt Lake. The Hansel Mountains, which rise to a height of about 8,000 feet, are separated at their north end from the Promontory Range by a pass that forms a low divide between Curlew and Hansel valleys. (See Pl. I.) Hansel Valley is a smooth débris-filled basin which drops by easy stages from the pass to the level of the lake. Irregularities in the topography are found near Rozel, where the Rozel Hills and Spring Bay Hill, composed of indurated strata, project through the valley fill to a height of a few hundred feet. The drainage of the main part of the valley passes north of the northernmost of these hills and discharges into Spring Bay, but the drainage of the part of the valley lying east of the hills passes southward near Rozel. A tract of low swampy land contours the lake and at the head of Spring Bay extends into the valley to the Salt Wells.

All of Hansel Valley was flooded by Lake Bonneville, the waters covering the Rozel and Spring Bay hills and the pass between Hansel and Curlew valleys. (See fig. 2, p. 13.) The shore lines are high on the mountain sides and the alluvial slopes are high and narrow. The valley floor, however, unlike that of most valleys in this region, is not flat except near the north end. South of the spur of Promontory Range that extends into the valley a few miles above Salt Wells the floor descends to a narrow channel which leads into the swamp.

GEOLOGY.

The strata exposed in the Hansel Mountains are mostly limestone and quartzite, but the range is covered near the south end by lava.[1] The rocks appear to lie in a nearly horizontal position and they outcrop on both sides of the range. A heavy lava bed lies northeast of the valley and forms a conspicuous but narrow table which extends southeastward from a point in the pass along the west flank of Promontory Range to the spur that projects into the valley from the range. The Rozel and Spring Bay hills are composed of Carboniferous limestone capped by a thick bed of lava. The valley fill extends to an unknown depth. The deepest well is 405 feet deep and is reported to have been drilled entirely in the unconsolidated sediments, though at the bottom it reached material resembling brecciated lava.

VEGETATION.

The native vegetation in this valley is of the semidesert type. The sagebrush zone is limited to the higher portions of the alluvial slope and the area north of the State well. Stunted shadscale covers the lower slopes and the central flat except near the swampy tract, where greasewood predominates. Salt grass and bulrushes are the chief types present on the swamp below the Salt Wells. Juniper trees are prevalent in the vicinity of Cedar Springs and in a few places on the mountain sides, and pines and cedars grow on the Hansel Mountains.

DEVELOPMENT.

There has been but little industrial development in this valley. The scarcity of springs and streams prevented settlement by irrigation farmers, and the difficulty of obtaining ground-water supplies for domestic use has in late years retarded settlement by dry farmers. The settlement has been mostly temporary, the farmers residing in the valley only during the harvesting and planting of dry-farm crops. The cultivation of wheat, the principal product raised for market, has already had fairly good results, and crops of this staple will perhaps be more successful as the farms are placed in better condition.

SPRINGS.

There are but few springs in this valley. (See Pl. I, in pocket.) Dillies Spring, at the north end of the valley, is a seepage of about 15 gallons a minute, which has been piped to Dillie's ranch. The so-called "salt wells," a group of springs in sec. 16, T. 12 N., R. 7 W., furnish brackish but drinkable water. These springs come out around the edge of the swamp only a few feet above the lake and therefore

[1] Hague, Arnold, Rept. U. S. Geol. Expl. 40th Par., vol. 2, 1877, p. 424.

at the ground-water level. The water flows over the swamp toward the lake, keeping it well supplied and rendering it a coveted area for stock raising. Cedar Spring, in sec. 35, T. 11 N., R. 7 W., emerges from the base of the terrace that marks the Provo shore line and discharges about 2 gallons a minute of fairly good water. Mud Spring issues from the ground in sec. 7, T. 9 N., R. 6 W., and has a flow not exceeding 3 gallons a minute. The railroad company has piped the water from a mountain spring to Rozel station, where water can be obtained by transients.

WELLS.

The development of ground-water supplies in this valley has been hindered by two unfavorable conditions: The water table over a large part of the valley lies at such depths that the expense of drilling renders water from this source almost prohibitive to persons of small means; and the wells thus far drilled in the lower parts of the valley have furnished only salty water. Three wells in the upper part of the valley yield good water. The State well, now owned by W. M. Greaves, in sec. 14, T. 13 N., R. 7 W., was drilled to a depth of 405 feet, the water rising to a level 225 feet below the surface. The Chritchlow well, in sec. 10, T. 12 N., R. 7 W., obtained water at a depth of 350 feet, the water rising to a level 300 feet below the surface. This well is reported to have passed through 60 feet of disintegrated material, then to have encountered a bed of hard cemented gravel 100 feet thick, and to have ended in sandstone which yields water of low mineral content, but too warm to be palatable. A well in sec. 15, T. 11 N., R 7 W., obtained water high on the alluvial slope at a depth of 112 feet, but its supply is small. A well drilled in sec. 14, T. 12 N., R. 7 W., encountered at 50 feet water too salty even for stock. Drilling was continued to 150 feet, but no better water was found, and the well was abandoned. Several wells drilled on the flat south of Rozel have been abandoned because the water in them is unfit for use. Water for domestic use will probably be found on the lower slopes above Salt Wells and in the vicinity of Rozel at shallower depths than in the wells already drilled, and other deep wells may be drilled in the vicinity of the State well. Precaution should be taken not to sink the holes in close proximity to rock outcrops, as the chances of obtaining water are greatly reduced in such places. (See fig. 7, p. 28.) Heavier drilling machinery than that commonly used in this part of Utah could be operated more successfully. The type known as the churn drill is best adapted for sinking deep wells, as it is less likely to be turned aside by a bowlder or hard stratum than are the light hydraulic drills that are frequently used.

It is not likely that much ground water can be developed for irrigation. The cost of pumping water more than 50 feet prohibits its

use for ordinary crops. It is probable, however, that where successful wells for domestic use are obtained the supplies will be adequate for watering gardens and small orchards and even this amount of irrigation will add materially to the comfort and welfare of the residents on dry farms.

QUALITY OF WATER.

The two samples of water that were tested from Hansel Valley represent supplies carrying moderate amounts of mineral matter. The waters could probably be used for irrigation without trouble from accumulation of alkali, and they are potable. They are somewhat high in scaling constituents, but could be improved by treatment with lime and soda ash.

Assays of water from Hansel Valley, Utah.

[Parts per million.]

No.	Owner.	Location.	Source.	Depth of well.	Depth to water.	Calcium and magnesium (Ca+Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).
141	Mr. Dillie [a]	Sec. 27, T. 14 N., R. 7 W.	Spring			[c] 210	[c] 70	0.0	225	30	110
142	Wm. Greaves [b]	Sec. 14, T. 13 N., R. 7 W	Drilled well.	405	225	96	58	8.0	180	27	146

No.	Hardness.	Total dissolved solids.	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.	Quality for boiler use.	Quality for domestic use.	Alkali coefficient.	Quality for irrigation.	Mineral content.	Chemical character.
								In.			
141	225	[c] 450	250	190	N. C.	Poor	Good	18.5	Good	Moderate	Ca—CO_3
142	[c] 275	543	300	155	(?)	Poor	Good	14.0	Fair	High	Ca—CO_3

[a] Field assay. [b] Analyzed by Jas. R. Bailey, Austin, Tex. [c] Calculated.

CURLEW VALLEY.

TOPOGRAPHY.

Curley Valley lies north of Great Salt Lake and is bounded by the Hansel Mountains and Promontory Range on the east and by the Black Pine Mountains, the Raft River Mountains, and the Kelton escarpment on the west. It comprises about 725 square miles of hills and lowland and extends about 15 miles north of the Utah-Idaho State line. (See Pl. I, in pocket.) The Promontory Range, which forms most of the eastern boundary of Curlew Valley, extends from the pass about 5 miles southeast of Snowville northward beyond the limits of this valley. Throughout this distance it maintains a

general height of nearly 8,000 feet, and the highest peaks reach still greater altitudes. The Hansel Mountains, which form the eastern boundary south of Snowville, culminate in a high peak near the pass and gradually become lower toward the south. Their west slope descends in a series of rock terraces overlooking the valley. The western boundary, unlike the eastern, is not a continuous wall. The Black Pine and Raft River mountains are both lofty ranges, the former rising to an altitude of 9,000 feet and the latter to about 8,000 feet, but between these ranges is a broad open pass, and south of the Raft River Mountains the divide follows a line of low hills and escarpments. The northern boundary is formed by a range of hills to which no names have been applied. The Showell Hills project southward as a spur of this range and separate the northern part of the valley into two arms. The southern part of the valley is an open plain which a few miles north of Kelton and Monument is interrupted by a series of hills that extend from the Hansel Mountains nearly to the Kelton escarpment. These hills are more or less isolated from each other, and the flood waters drain to Great Salt Lake through the low areas between them.

GEOLOGY.

The geology of the Hansel and Promontory ranges has already been described (p. 56), and the Raft River Mountains and Kelton escarpment are treated in connection with Park Valley (pp. 64–65). The Black Pine Mountains are composed mainly of white quartzite and micaceous schists of probable early Paleozoic age, but younger Paleozoic rocks may occur in places surrounding the main mountain mass. The Showell Hills are composed of grayish limestone and quartzite, which in most places are concealed by the Lake Bonneville sediments. So far as could be determined, the limestone and quartzite beds have a slightly northward inclination. The isolated hills in the south part of the valley were not visited, but are reported to contain limestone overlain by a bed of lava. Indurated strata are also exposed in the valley fill east of the Raft River Mountains, and lava is found in several places at the surface or only a few feet below it. The geologists of the Survey of the Fortieth Parallel report the lava to be well developed in the area south of the isolated hills.[1]

The unconsolidated sediments of this area are mostly lake deposits, the waters of Lake Bonneville having occupied nearly all of the valley. In the vicinity of Great Salt Lake the shore lines are high on the mountain sides, but the valley floor rises toward the north to such an extent that the Bonneville shore line crosses the western arm a few miles above the State line. (See fig. 2, p. 13.) The thickness of the unconsolidated sediments in this valley has not been determined.

[1] Hague, Arnold, Rept. U. S. Geol. Expl., 40th Par., vol. 2, 1877, p. 425.

The artesian wells at Kelton are said to end in unconsolidated material at a depth of about 500 feet, and according to an unverified report a well 1,600 feet deep was once drilled at this station without reaching bedrock.

PRECIPITATION.

Rainfall gages have been maintained at Kelton and Snowville for a number of years. The records for these stations, given on page 18, show that the precipitation is heavier in the northern part of the valley than in the southern part, the annual average being 11.50 inches at Snowville and only 6.37 inches at Kelton. If only those years are considered for which complete records were kept at both stations the averages are respectively 11.56 inches and 6.59 inches. This difference in precipitation between the north and south parts of the valley is due without doubt to the high mountains which surround the north end of the valley. The average for July is the same at both stations but for the other months of the year it is from 0.4 inch to 2.2 inches higher at Snowville than at Kelton. (See fig. 6, p. 21.)

DEVELOPMENT.

The Central Pacific Railroad was completed in 1869, but there was little industrial development until a later date. The farming industry was for a long time confined to the eastern arm, where water for irrigation was available. In recent years attempts have been made to raise crops without irrigation. On the sage-brush land near the north end of the valley dry farming has had promising results, but on the shadscale flat west of Showell it has been unsuccessful, the failures being due in part to improper cultivation and in in part to insufficient rainfall.

VEGETATION.

The banded arrangement of the vegetation commonly found in most of the valleys of the Great Basin is not present over a large portion of Curlew Valley. The north end of the valley is covered with a dense growth of sage, but most of the area south of the Utah-Idaho State line is covered with intermittent traces of shadscale and sage. Near the lake greasewood and rabbit brush prevail.

STREAMS AND SPRINGS.

Deep Creek, the only permanent stream in this valley, has its source in the mountains surrounding the eastern arm and flows southward past Holbrook, Stone, and Snowville, to the ranches at Showell, where the last of its waters percolate into the soil or are evaporated from the surface. In its upper course this stream car-

ries but little water except during floods, but in secs. 12 and 13, T. 15 S., R. 32 E. Boise meridian, it receives the water of a number of springs whose combined flow, according to a report of the Pratt Irrigation Co., is about 40 second-feet.

The Pratt Irrigation Co. has constructed a canal to divert the entire flow of these springs to land west of Stone, Idaho, where about 6,000 acres are to be irrigated, and has built a reservoir in which to store flood waters and the winter flow of the springs, which is to supply the farms at Snowville and Showell. In 1911 practically no water was delivered to the land west of Stone because of the unstable condition of the ditches, and no crops were raised by irrigation in that tract. The Utah-Idaho Land & Water Co. has constructed a reservoir in sec. 9, T. 14 N., R. 8 W., from which several hundred acres north and west of Showell are to be irrigated. Much difficulty was experienced in 1911 on account of leakage. If this project proves successful another reservoir is to be built farther downstream.

A number of springs issue along the foot of the Promontory range between sec. 5, T. 14 N., R. 7 W. Salt Lake meridian, and sec. 6, T. 16 S., R. 33 E. Boise meridian, which yield sufficient water to irrigate small fields. Another series of springs is found along the foot of Black Pine Mountains between sec. 19, T. 16 S., R. 30 E. Boise meridian, and the north margin of that township. Isolated springs are also found in several other localities. (See Pl. I, in pocket.)

WELLS.

Artesian wells, reported to be 500 feet deep, were obtained at Kelton a number of years ago and are still flowing. The water which they yield is unfit for irrigation, especially on the alkali soil at that place (see assay, p. 64). Three wells in the NE. ¼ sec. 25, T. 16 S., R. 32 E. Boise meridian, were sunk in ground occupied by seepage springs and obtained small flows at a depth of 40 feet. In many of the nonflowing wells the water rose several feet above the level where it was first encountered, and in Bishop Roe's well it rose about 80 feet above the water-bearing stratum.

In the eastern arm, north and east of Snowville, a number of nonflowing wells have been obtained. The water was found at various depths but in general is deepest near the north end and is always deeper on the slopes bordering the Showell Hills than on the slopes along the Promontory Range. The domestic supply for Snowville was formerly obtained from wells but is now piped from a spring due east of town. The wells yield water of poor quality and have been abandoned. The well in sec. 5, T. 15 S., R. 30 E., which struck water at 75 feet, is the only successful well so far obtained in the western arm. A well is reported to have been drilled in the SE. ¼

sec. 1, T. 16 S., R. 30 E., which obtained water at 390 feet that rose to a level 240 feet below the surface, but the well was not cased and was consequently ruined by caving.

A well dug on the Showell ranch to a depth of 60 feet obtained water that rose to the 50-foot level, but another well 90 feet deep and less than a quarter of a mile away stopped in lava without obtaining water. A well was dug by J. H. Meekum at Cedar Store, in sec. 12, T. 14 N., R. 12 W., to a depth of 85 feet, where water was obtained. The Baker well in sec. 8, T. 12 N., R. 8 W., which is reported to have been dug to a depth of 92 feet and to have passed through 52 feet of lava, obtained a good supply of water. (See Pl. I, in pocket.)

Many of the failures in sinking for ground water in this valley have been due to the half-hearted attempts that were made. At probably no place in the valley is it impossible to obtain water, except in the areas close to the mountains or near outcropping ledges of rock. Even in localities where lava has been encountered water can perhaps be found either in cracks in the lava itself or in porous beds beneath it. More success could be had in drilling by using heavier machinery equipped for passing to considerable depths through all kinds of material. The type commonly known as the churn drill is well adapted for use in this valley.

The base of the slopes east of the Black Pine and Raft River Mountains are promising localities for future development. Water of good quality will probably be obtained in those localities and it is not unlikely that a sufficient quantity for considerable irrigation can be recovered. Water will probably be found (at greater depth) in the broad area between Snowville and Cedar Store and also south of the isolated hills, but it may be of inferior quality.

QUALITY OF WATER.

The ground water in this valley is somewhat high in its content of chlorine, the assays showing amounts ranging from 110 to 910 parts per million. Bicarbonates and hardening constituents are not excessive and only one sample showed a high content of sulphate. The water from Pilot Spring and that from the artesian wells at Kelton each had 40 parts and that at Snowville 10 parts per million of normal carbonates. The following table gives the results of 8 assays of water. Three of the waters are fair for boiler use and the same number for domestic use. Only one sample is classified as good for irrigation, but it is thought that several of the others may be applied to land that has good underdrainage.

Assays of ground water from Curlew Valley.

[Parts per million.]

No. of sample.	Owner.	Location.	Source.	Depth of well.	Depth to water.	Calcium and magnesium (Ca+Mg).[a]	Sodium and potassium (Na+K).[a]	Total hardness as $CaCO_3$.	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.[a]	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.	Quality for boiler use.	Quality for domestic use.	Alkali coefficient.	Quality for irrigation.	Mineral content.	Chemical character.
				Ft.	*Ft.*														*In.*			
130	....	Sec. 13, T. 14 N., R. 11 W.	Pilot Spring.	....	....	100	70	265	40	190	30	110	500	300	720	......	Bad.....	Fair..	18	Good.	Moderate..	Ca—CO_3
131	Snowville waterworks.	Snowville......	Spring......	....	....	120	220	370	10	205	45	430	1,040	400	1,000	......	...do.....	...do..	4.7	Poor.	High......	Na—Cl
132	Richard Allen....	Stone Post Office, Idaho.	Dug well....	19	17	45	980	110	0	360	430	910	2,440	140	300	N. C.	Fair.....	Poor.	1.3	...do..	Very high.	Na—Cl
133	Lorenzo Hurd....	SW. ¼ sec. 19, T. 16 S., R. 33 E.[b]	.....do......	14	9	95	320	240	0	385	30	365	1,000	270	650	N. C.	Bad.....	Fair..	3.5	...do..	High......	Na—Cl
134	A. P. Peterson...	Sec. 25, T. 15 S., R. 33 E.[b]	Drilled well.	105	....	80	290	200	0	345	55	315	930	230	540	N. C.	...do.....	...do..	3.9	...do..	.....do....	Na—Cl
135	....	NE. ¼ sec. 7, T. 15 S. R. 33 E.[b]	.....do......	110	....	70	630	175	0	335	255	630	1,700	200	470	N. C.	Fair.....	Poor.	1.7	...do..	.....do.....	Na—Cl
140	George Showell...	NW. ¼ sec. 11, T. 14 N., R. 11 W.	Dug well....	60	50	100	470	265	0	285	285	470	1,500	300	720	......	Bad.....	Fair..	3.0	...do..	.....do.....	Na—Cl
122	Stone & Paine...	Kelton.........	Drilled well.	500	Flowing.	25	640	60	40	145	68	775	1,500	100	160	N. C.	Fair.....	Poor.	1.8	...do..	.....do.....	Na—Cl

[a] Calculated.

[b] Boise Meridian.

IRRIGATION WITH GROUND WATER.

So far as can be determined from the present ground-water development, it will not be advisable to attempt extensive irrigation over most of this valley. It may be found feasible to irrigate with well water a strip bordering the Promontory Range in the eastern arm in the area where the water table lies less than 50 feet below the surface. Future development may also prove that the slopes east of the Black Pine Mountains contain sufficient water for irrigation, but the supply can be determined only by drilling. Water can be lifted a greater distance for irrigating orchards and gardens than for most field crops. It will probably be possible, therefore, to employ pumps over a large part of the eastern arm in the intensive cultivation of small tracts that will be remunerative and will make life on the dry farms more pleasant.

PARK VALLEY.

TOPOGRAPHY AND GEOLOGY.

Park Valley is a broad, irregular-shaped plain about 30 miles long in an east-west direction and about 10 miles wide. It slopes southward from the foot of the Raft River Mountains at the rate of about 150 feet to the mile. The low divide in the southwestern part of the valley separates the drainage into two basins; the water from the Raft River Mountains passes into Dove Creek but most of that from the Grouse Creek Mountains is discharged through Muddy Creek.

The Raft River Mountains, which attain an elevation of nearly 9,000 feet above sea level and more than 4,000 feet above the lowest part of the valley, form the north boundary of the valley. These mountains constitute a large anticline the southern flank of which dips about 25° S. and projects beneath the valley. The rocks exposed are mainly of early Paleozoic age. They consist chiefly of white quartzites and micaceous schists, but limestones are found along the foothills and in the pass leading to Junction Creek.

The Grouse Creek Mountains, which limit the valley on the west, contain strata that are similar to those exposed in the Raft River Mountains but that dip toward the west and form a steep scarp slope on the east. Granite forms the core of the southern part of the range,[1] where it outcrops over an area 10 to 12 miles long and 6 to 8 miles wide. At the south end the granite is covered by beds of limestone which were referred by Hague to the "Lower Coal Measures." The western slope of the range is covered high up on the flank by heavy beds of fine, white pumiceous sands, loose sandstone, and fine conglomerates which have been referred to the Pliocene.

[1] Hague, Arnold, Rept. U. S. Geol. Expl. 40th Par., vol. 2, 1877, p. 428.

The region lying between Park Valley and Great Salt Lake Desert contains a group of irregular hills which at but few points rise above the level of the Bonneville shore line. They are composed in large part of gray limestones intruded by lava and partly concealed by lava and lake sediments. Southeast of these hills, along the west side of the lake, the Terrace Mountains attain an elevation of nearly 7,000 feet above the sea, or about 2,700 feet above the present lake level. They are composed chiefly of limestones which have a gentle northwest dip.

The eastern margin of the valley is formed by an abrupt break in the topography, known as the Kelton escarpment, which probably marks the position of an ancient fault. This eastward-facing scarp is capped by a thick bed of lava that appears to extend westward beneath the Tertiary and Quaternary sediments.

Park Valley is underlain by Tertiary and Quaternary beds. When Lake Bonneville stood at its highest level its waters covered only a part of the valley (fig. 2, p. 13), and the Quaternary beds are therefore partly stream deposits and partly lake deposits. Above the shore line the beds consist largely of coarse stream-deposited gravel and sand, but below the shore line, along Birch and Dove creeks, they include typical fine-grained lake sediments. The unconsolidated material that underlies the valley is probably thin in most places. The only two deep wells that have been sunk penetrated rock. All of the other wells in the valley are shallow and end in the Quaternary beds. Lying below this thin covering of Quaternary deposits and in few places appearing at the surface is a series of conglomerates, shale, and soft limestone of probable Tertiary age. A bed of hard yellow conglomerate, 200 feet thick, is exposed on the west bank of Indian Creek, south of the wagon road leading between Showell and Park Valley, and rocks of similar character outcrop on the hill in the NW. ¼ sec. 25, T. 13 N., R. 13 W. Thick beds of bluish and yellowish clays are exposed on Indian Creek a few miles above the wagon road. Fine-grained yellow limestone forms the large hill southwest of Rosette. This limestone was encountered in the well of James Hirsche in sec. 2, T. 12 N., R. 14 W., and in the well in the SE. ¼ sec. 8, T. 12 N., R. 13 W. It is also exposed in a few places along the streams flowing south from the Raft River Mountains.

VEGETATION.

Sage brush from 2 to 5 feet in height covers a large area in the northeastern part of the valley, but stunted brown shadscale is the predominant plant over the rest of the region. Greasewood, except for a very few scattered tracts along Birch Creek, is found only as isolated plants. The area between Rosette and Indian Farm contains a large number of scattered juniper trees and the mountains

to the north and west are well timbered with pine and cedar. Rainfall observations have not been made, but the arrangement of the vegetation indicates that the northeastern part of the valley receives a more copious rainfall than other parts of the valley.

STREAMS.

Park Valley receives the drainage from the mountains on the west and north. The two largest streams are Birch and Dove creeks. They flow continuously in their upper courses, but their waters sink into the loose soil soon after they enter the valley proper. Birch Creek rises in the Grouse Creek Mountains and flows southeastward across the southwestern part of the valley. Dove Creek rises in the pass that leads to Junction Creek and also flows southeastward. Five small but important streams rise in the Raft River Mountains and furnish most of the irrigation supply. Named in order from west to east they are Dry, Pine, Rock, Fisher, and Marble creeks.

No permanent streams flow out of the valley, but the flood waters discharge through the channels of Birch and Dove creeks into the desert and lake. These streams flow southeastward to a point near the low hills that form the southern boundary of the valley, where they take an almost due south course through gaps in the hill region.

SPRINGS.

Springs of the seepage type are found in the northeastern part of the valley on the land over which the streams from the Raft River Mountains flow. They are most abundant in the vicinity of the Park Valley stores and Rosette, where they have been an important factor in the development of the valley. The bed of Birch Creek from the vicinity of Herrington's ranch to the south side of sec. 22, T. 11 N., R. 15 W., is low and swampy (Pl. I) and contains numerous small springs. The discharge of the seepage springs throughout the valley varies notably with the season, their yield being greatest in summer and least in winter. This fluctuation shows that the ground water corresponds to the seasonal variation in precipitation.

Warm Spring, situated in sec. 20, T. 12 N., R. 15 W., appears to be caused by some geologic structure, its flow, which amounts to about 2 second-feet, being practically constant throughout the year.

FLOWING WELLS.

Two wells in this valley yield water by artesian pressure. The James Hirsche well, in sec. 2, T. 12 N., R. 14 W., was drilled 205 feet through the Tertiary limestone and is reported to have ended in gravel, where the flow was obtained. At present it yields only about 2 gallons a minute, but the driller reports that when it was com-

pleted the water rose about 18 inches above the outlet. The Rosevere well is located in the valley of Dove Creek, on sec. 18, T. 12 N., R. 14 W. It was drilled a number of years ago and very little could be learned in regard to its depth and yield, but it is reported to end in unconsolidated material at a depth of about 50 feet. The water rises to a level 2 feet below the surface and is brought to the surface by means of a trench leading to lower ground.

Flows could possibly be obtained from the unconsolidated Quaternary sediments in certain small areas, as in the shallow water tracts along Birch and Dove creeks, but over most of the region the water from these sediments will not rise to the surface. Even where the water table is near the surface flows can not generally be obtained, because the sediments are too thin and too porous to allow an accumulation of water under pressure.

The conditions controlling the water in the Tertiary strata have not been thoroughly tested. It is possible that beds of gravel or some other porous material are present beneath the compact limestone which seems to underlie most of the valley and that these beds contain water that would rise to the surface or to a level from which it could be profitably pumped. The actual conditions can be determined only by sinking a deep test well. The cost and uncertainty of such a test would be so great that it could not wisely be made by any one inhabitant of the valley, but in view of the remote possibility of obtaining supplies from this source it might not be inadvisable for the community as a whole to make the test. Such a well to have the best chance of success should be located in the lower part of the valley, probably near the south line of T. 12 N.

NONFLOWING WELLS.

The Quaternary deposits in the northeastern part of the valley are saturated with water to a level near the surface, and no difficulty has been experienced by the farmers in this part of the valley in obtaining ground-water supplies. Differing from most débris-filled valleys, the water table is found nearest the surface at the foot of the mountains and deepest in the lowest part of the valley, the depth to water ranging from 8 to 56 feet in the wells that have been sunk.

Only a few successful wells have been obtained west of the Rosevere ranch, which is situated in sec. 18, T. 12 N., R. 14 W. Two wells have been dug near the channel of Birch Creek, at the Hyland ranch, in sec. 16, T. 11 N., R. 15 W. The indurated strata come near the surface at the west side of T. 11 N., R. 15 W., and seem to form an underground dam which has impounded the water and caused it to overflow in the channel of Birch Creek. Good wells can probably be obtained over a small area lying west of that locality along the base of the alluvial slopes.

The water level of the wells of Park Valley undergoes a seasonal fluctuation corresponding to the fluctuation in the flow of the springs, the level being highest in summer and lowest in winter.

QUALITY OF WATER.

The ground waters in Park Valley are good for domestic use. In the samples tested chlorides ranged from 60 to 355 parts per million, total hardness from 90 to 215 parts, bicarbonates from 45 to 385 parts, and sulphates from less than 30 to 110 parts. The water from Hirsche's flowing well contains 75 parts per million of normal carbonates, from which the other waters were free. The waters were generally bad for boiler use and are classified as poor for irrigation. It is believed that the waters may be used for irrigation, as the ground is porous and has free drainage, but great care would have to be exercised to prevent undue accumulation of alkali.

Assays of water from Park Valley, Utah.

[Parts per million.]

No.	Owner.	Location.	Source.	Depth of well.	Depth to water.	Calcium and magnesium [a] (Ca+Mg).	Sodium and potassium [a] (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Hardness as $CaCO_3$.	Total solids.[a]	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.	Quality for boiler use.	Quality for domestic use.	Alkali coefficient.	Quality for irrigation.	Mineral content.	Chemical character.
				Ft.	Ft.														In.			
114	....	SE. ¼ sec. 1, T. 11 N., R. 16 W.	Spring....	....	....	70	200	0	240	(b)	125	175	440	200	540	N.C.	Fair....	Fair..	4.4	Poor.	High....	Na—Cl
115	Frank Highland..	Southwest corner sec. 16, T. 11 N., R. 15 W.	Dug well..	9	7	70	435	0	340	110	335	175	990	200	1,160	N.C.	Very bad.	...do.	2.4	...do.	...do.....	Na—Cl
116	Henry Peterson...	North center NW. ¼ sec. 8, T. 12 N., R. 14 W.	.....do....	15	13	40	225	0	170	(b)	195	95	500	125	610	N.C.	Bad.....	...do.	4.4	...do.	Moderate.	Na—Cl
117	James Hirsche....	North center NW. ¼ sec. 2, T. 12 N., R. 14 W.	Drilled well.	205	Flowing.	35	155	75	45	(b)	85	90	350	125	420	(?)	Fair.....	Good	5.8	...do.	...do.....	Na—CO_3
120	J. H. Meekum.....	Southwest corner sec. 22, T. 13 N., R. 13 W.	Spring....	....	....	70	215	0	385	(b)	60	175	470	200	580	N.C.	Bad.....	Fair..	3.7	...do.	...do.....	Na—CO_3
121	Pacific Land & Water Co.	SE. ¼ sec. 8, T. 12 N., R. 13 W.	.....do....	....	....	80	220	0	265	(b)	135	205	500	235	590	N.C.	...do....	...do..	4.1	...do.	...do.....	Na—Cl
124	Thomas Stirland..	Southwest corner NW. ¼ sec. 22, T. 12 N., R. 13 W.	Dug well..	32	27	80	385	0	255	60	355	205	780	235	1,040	(?)	Very bad.	...do..	2.6	...do.	High....	Na—Cl
125[c]	Chas. W. Goodliffe	Southeast corner sec. 28, T. 13 N., R. 13 W.	.....do....	11	9	75	110	15	315	35	105	225	535	255	300	N.C.	Poor....	...do..	2.2	Good	...do.....	Na—CO_3
126	Ole Olsen	Southeast corner sec. 23, T. 12 N., R. 14 W.	.....do....	58	53	85	265	0	350	(b)	150	215	535	245	710	N.C.	Bad.....	...do..	3.3	Poor.	...do.....	Na—CO_3

[a] Calculated, except in the analysis by J. R. Bailey.
[b] Less than 30 parts per million.
[c] Analyzed by J. R. Bailey.

IRRIGATION.

About 6,000 acres of land in Park Valley are irrigated with surface water, about 5,700 acres being supplied by the streams issuing from the Raft River Mountains, in the northeastern part of the valley. Birch Creek supplies water for about 150 acres on the Warren, Herrington, and Hyland ranches, and Dove Creek and Warm Springs together supply water for about 150 acres on the Rosevere and Clark ranches.

Up to the present time irrigation with ground water has not passed the experimental stage. Two gardens were being irrigated with underground water in 1911. A pumping plant, consisting of a 2-horsepower gasoline engine and suction pump, has been installed by Charles W. Goodliffe at the Park Valley store. The well is about 10 feet in diameter and 17 feet deep, the water standing at a level 11.4 feet below the surface. Gasoline costs 22 cents a gallon at Kelton, 13 miles away, and the rated consumption is 1 gallon an hour per horsepower, but the actual cost of operation, including fuel and oil, was estimated by the owner at 2½ cents an hour. The yield, measured half an hour after pumping was begun, was 27 gallons a minute. The water level was lowered to 14 feet at the end of three hours' pumping, the yield remaining practically the same. The cost of water at this rate of pumping and estimated expense of operating is $5.22 an acre-foot.

The other pumping plant belongs to Charles Chadwick and is situated in sec. 4, T. 12 N., R. 13 W. It consists of a 2-horsepower gasoline engine and a suction pump. The well is 3 feet in diameter and 32 feet deep and has a water level 11.7 feet below the surface. The cost of operation is practically the same as at the Goodliffe plant. A yield of 31 gallons a minute was maintained during a brief test and the cost of fuel was estimated as $4.37 an acre-foot of water. This cost can be reduced in plants of larger capacity. At neither of these plants was the engine running under full load.

Much of the water that sinks into the surface deposits near the mountains travels slowly toward the lower parts of the valley through the loose material lying on top of the Tertiary limestone, but a part probably follows down the top of the Paleozoic strata into gravel beds.

Wells of large diameter sunk to the bottom of the unconsolidated sediments or at least to considerable depths below the water level will generally yield enough water for the irrigation of a few acres. If larger supplies are desired several wells should be sunk at equal distances apart, preferably along an east-west line, and these wells should be connected by tunnels in order that water from all of them can be drawn by means of a single centrifugal pump. A comparatively large quantity of ground water of considerable economic importance can no doubt be obtained if the wells are widely distributed, but there is no warrant for believing that the supply is

sufficient to irrigate all or even any large portion of the total arable land, as is represented by some persons. Pumping plants could probably be employed advantageously on land now irrigated with stream water to provide supplies during the later part of the growing season, when the flow of the streams diminishes. The most profitable use on other lands will be in enabling the farmers to supplement dry-farm crops by some that require water to bring them to maturity. Orchards, gardens, shade trees, and small fields of alfalfa may be grown, and life on the dry farms will thereby be made more pleasant and profitable.

GROUSE CREEK VALLEY AND PILOT MOUNTAIN AREA.

TOPOGRAPHY AND GEOLOGY.

Grouse Creek valley is a relatively narrow tract lying between the Grouse Creek and Goose Creek mountains. It extends from a point near the Grouse Creek settlement in a general southerly direction to the vicinity of Lucin, a distance of about 25 miles. (Pl. I, in pocket.) The Goose Creek Mountains, which are composed chiefly of Carboniferous limestone, rise abruptly to a height of nearly 2,000 feet above the valley, or about 7,000 feet above sea level. They have been subjected to faulting and to the intrusion of lavas, typically developed near the Etna post office. The Grouse Creek Mountains have been described in connection with Park Valley. (See p. 64.) Pliocene deposits, consisting chiefly of clay, sand, and volcanic ash, occur on the west slope of these mountains and on the divide between Mahogany and Etna creeks. (See Pl. I.)

When Lake Bonneville reached its highest level the valley was a long, narrow bay that terminated near the Grouse Creek settlement. The water of this bay deepened toward the south and stood about 700 feet above the present site of Lucin. Twin Mounds and the large hill about 6 miles north of Lucin were islands, but the other buttes in the valley were completely covered. During this submergence the valley was filled to a considerable depth by beds of sand, clay, and gravel, which have been exposed in sec. 33, T. 8 N., R. 18 W., to a depth of 15 feet by postlacustrine erosion and have also been penetrated by a number of shallow wells.

Lying between the Tecoma and Pilot mountains on the west and Great Salt Lake Desert on the east is a dry, parched plain, barren except for a scant growth of grayish shadscale. The Pilot and Tecoma mountains form a continuation of the Goose Creek Mountains to the north and rise to a height of 10,000 feet above sea level, or approximately a mile above the level of Great Salt Lake. They are composed of indurated strata ranging in age from pre-Cambrian to Carboniferous. The Bonneville shore line follows the sides of the

mountains, high above the plain. A number of low hills composed of indurated strata project through the unconsolidated sediments of the plain. The part of the plain adjacent to the Tecoma Mountains descends to the desert by easy stages, but that adjacent to the Pilot Mountains has a rather steep descent along which there are many springs.

PRECIPITATION AND VEGETATION.

Rainfall data have been collected at Lucin since January, 1909, and at Grouse Creek settlement since July, 1910. The average annual precipitation at Lucin for the three years is only 4.09 inches, but more rain falls at Grouse Creek than at Lucin, as is attested both by the records and by the vegetation. In figure 8 the rainfall at the two stations is compared for each month during which both have records.

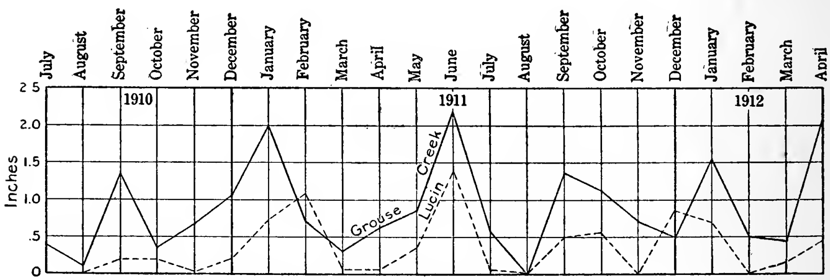


FIGURE 8.—Diagram showing relation of precipitation at Grouse Creek and Lucin, Utah.

The extremely arid climate of the lower portions of western Boxelder County produces typical desert vegetation. The high mountains contain a relatively abundant supply of pine, cedar, and other mountain trees. The tops of the alluvial slopes support juniper trees and sage brush and the lower slopes vast tracts of shadscale. On the low tracts along Grouse Creek and on the margin of the desert luxuriant greasewood and rabbit brush prevail, but the desert is void of vegetation.

STREAMS AND SPRINGS.

The largest streams in this vicinity are Etna and Mahogany creeks, whose channels unite to form Grouse Creek. They are fed by mountain springs and run during the entire year, although their flow is small in July and August. Their normal flow is all appropriated on land lying in the upper part of the valley, Etna Creek supplying water for about 750 acres and Mahogany Creek for nearly 1,000 acres. The large floods caused by heavy rains or melting snow reach beyond Lucin, sometimes overflowing the bottom land to a depth of 4 feet or more, but at other times the water seldom reaches the junction of the two creeks.

Only a few springs occur in the valley, but there are many in the Grouse Creek Mountains. A spring has been piped to the Grouse Creek settlement for domestic supply. Kimber's Spring, in sec. 30, T. 10 N., R. 18 W., and Rabbit Spring, in sec. 14, T. 8 N., R. 18 W., are used to irrigate a few acres of land. The domestic and locomotive supply for Lucin is piped from springs in the Tecoma Mountains. Numerous springs issue along the margin of Great Salt Lake Desert from the foot of the alluvial slope bordering Pilot Range. The land on which they are found is too low and alkaline to be used for agriculture, but it is well supplied with native grasses.

WELLS.

There are but few wells in the western part of Boxelder County. At Grouse Creek settlement wells are obtained in the unconsolidated sediments at depths of about 25 feet, and along Etna Creek water is found at about the same depth. Two wells in the E. ½ sec. 28, T. 10 N., R. 18 W., procured a very small supply of water at 30 and 38 feet, but it is believed that larger supplies could be obtained at a greater depth. A number of wells now abandoned have in the past been sunk in the upper part of the valley. Among these are a well 50 feet deep dug 32 years ago by J. W. and Charles Kimber in sec. 16, T. 10 N., R. 18 W., a well 20 feet deep dug about the same time by a Mr. Duett in sec. 33, T. 11 N., R. 18 W., and a well 25 feet deep dug 18 years ago by Sam Kimber in sec. 27, T. 11 N., R. 18 W. The well of Sam Kimber could not be pumped dry with a windmill. In 1911 the bottom of the channel of Grouse Creek was moist, and in a few places, notably in the vicinity of Twin Mounds, several miles below the junction of Etna and Mahogany creeks, water was standing in potholes several months after the stream had ceased flowing. Where this condition exists the water table is probably not far below the surface.

QUALITY OF WATER.

The ground water of Grouse Creek valley is of relatively good quality for domestic use. Chlorides in the samples tested ranged from 30 to 215 parts per million, hardness from 115 to 235 parts, and bicarbonates from 145 to 675 parts. Only one sample contains more than 30 parts of sulphate and only one gave a reaction for normal carbonate. The waters are generally fair for boiler use. Four of the waters have been classified as good and three as fair for irrigation.

Assays of water from Grouse Creek valley, Utah.

[Parts per million.]

No. of sample.	Owner.	Location.	Source.	Depth of well.	Depth to water.	Calcium and magnesium (Ca+Mg).[a]	Sodium and potassium (Na+K).[a]	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Hardness.	Total solids.[a]	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.	Quality for boiler use.	Quality for domestic use.	Alkali coefficient.	Quality for irrigation.	Mineral content.	Chemical character.
																			In.			
106	Southern Pacific Co.	Sec. 24, T. 7 N., R. 19 W.	Spring	....	....	45	150	0	240	(b)	125	115	500	145	400	N. C.	Fair	Fair	7	Fair	Moderate	Na—Cl
077	Government land	North center sec. 36, T. 5 N., R. 19 W.	...do	....	....	50	65	0	190	(b)	50	130	320	160	175	...do	...do	Good	19	Good	...do	Na—CO_3
108	David Morrison	Center sec. 36, T. 4 N., R. 19 W.	...do	....	....	50	85	0	45	(b)	105	130	370	160	230	(?)	...do	...do	19	...do	...do	Na—Cl
109	C. C. Herrington	SW. ¼ sec. 14, T. 8 N., R. 18 W.	Rabbit Spring.	....	....	60	150	0	290	(b)	120	145	540	175	400	N. C.	...do	Fair	7	Fair	High	Na—CO_3
110	....	E. ¼ cor. sec. 28, T. 10 N., R. 18 W.	Dug well	38.5	38	95	180	0	315	(b)	215	235	700	265	485	...do	...do	...do	44	Good	...do	Na—Cl
111	W. J. Kimber	NW. ¼ sec. 30, T. 10 N., R. 18 W.	Spring	....	....	55	110	0	195	(b)	120	140	460	170	300	...do	...do	...do	16	Fair	Moderate	Na—Cl
112	Jas. Douglas	NW. ¼ sec. 32, T. 11 N., R. 18 W.	Dug well	20.0	12	80	340	0	675	145	135	205	1100	235	900	...do	Bad	Poor	3.7	Poor	High	Na—CO_3
113[c]	Grouse Creek, domestic supply.	Grouse Creek settlement	Spring	....	....	65	13	13	160	20	30	190	260	220	20	(?)	Poor	Good	68	Good	Moderate	Ca—CO_3

[a] Calculated quantities, except in the analysis by J R. Bailey.
[b] Less than 30 parts per million.
[c] Analysis by J. R. Bailey.

GROUND-WATER PROSPECTS.

Owing to the lack of irrigation supplies a large part of western Boxelder County has remained without permanent inhabitants, and hence there has been little incentive to drill or dig for ground water, development having been practically limited to the areas along Etna and Mahogany creeks. Nevertheless, in other places good water could probably be obtained by moderately deep wells.

The Pliocene strata which rest on the western slope of the Grouse Creek Mountains are in part porous, and they appear to extend beneath the unconsolidated lake beds that occupy the central part of Grouse Creek valley. Some of the water that falls as rain sinks into these porous strata and probably finds its way beneath the central part of the valley. There are, therefore, prospects for obtaining successful wells in the area that lies between the junction of Etna and Mahogany creeks and the Twin Mounds, and perhaps farther south. Owing to the fineness of the grain of these beds the yield of such wells will probably not be large but will be sufficient for farm supplies.

The lofty Pilot Mountains receive a large amount of rain and snow, and much of the resulting water doubtless finds its way into the loose gravel at the upper limits of the alluvial slopes and travels slowly to the lower levels, where it is in part delivered as springs and in part wasted by evaporation from the desert. This water could be recovered before it reaches the desert by moderately deep well sunk on the lower part of the alluvial slopes. Although there have been no developments it is not improbable that a strip of land one-half to three-fourths mile wide and 10 miles long, lying just above the line of springs, could be successfully irrigated by pumping from wells. In this strip the depth to water is probably less than 50 feet, and although it is not far above the desert it appears to be underlain by coarse material that would yield water.

TOOELE AND RUSH VALLEYS.

TOPOGRAPHY AND GEOLOGY.

Tooele and Rush valleys, in eastern Tooele County, occupy the structural trough between the Oquirrh and Onaqui ranges. (See Pl. II.) This trough opens at the north end to Great Salt Lake but is closed at the south end by the lofty Tintic Mountains. Near Stockton it is crossed by a low divide that separates it into two drainage basins known as Tooele and Rush valleys.

The Oquirrh Mountains, which form the east side of the trough, are about 30 miles long and from 5 to 10 miles wide. In the northern part they rise from 5,000 to 6,000 feet above the valley or nearly

10,000 feet above sea level, but in the southern part they are lower and are crossed by a broad pass leading into Cedar Valley. According to the geologists[1] of the Fortieth Parallel Survey this range is in the form of a broad dome whose crest is near the town of Ophir, and this fact has been reaffirmed by Keith[2] in his description of the Bingham mining district. The warped surface has also been chopped up into a great number of blocks by extensive faulting. The strata exhibited in the mountains consist in the main of quartzites, sandstone, and limestone, with intrusive bodies of monzonite and porphyry and andesite. The stratified rocks are of Carboniferous[3] age, but the age of the igneous rocks is not known except that they are later than Carboniferous.

The Onaqui or Stansbury Mountains, which form the western boundary of the trough, extend in a north-south direction parallel to the Oquirrh Mountains.[4] They culminate in Bonneville Peak, which is nearly 11,000 feet above sea level, or about 7,000 feet above the level of Great Salt Lake. South of Clover Creek the range is only about 5,000 feet above the surrounding valleys and is crossed by two wagon roads—one leading west from Clover through Reynolds Pass and the other west from Vernon through Point Lookout Pass. The geologic structure of the north half of this range is rather complex. In a large way the strata form an anticline whose axis has a north-south trend. Parallel to this axis they are traversed by a fault having an upthrow on the west side of about 10,000 feet. On the west side of the northern part of the range the strata dip 25°–45° W., and on the east side of the range they dip to the east from only a few degrees to about 90°. South of Reynolds Pass the strata dip at a low angle in a direction somewhat south of west and strike diagonally across the range.

South of Great Salt Lake and extending up the central part of Tooele Valley is a flat area that near the lake is low and marshy. On both sides of the central flat alluvial slopes reach upward to the Bonneville shore line, which is here about 5,200 feet above sea level, or 1,000 feet above Great Salt Lake. At the east end of the divide near Stockton the ancient lake formed a broad flat-topped beach ridge.

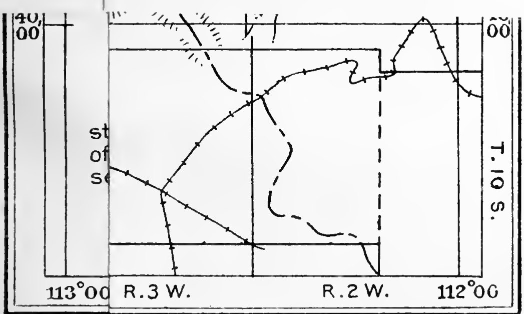
Rush Valley occupies the trough between the divide and the Tintic Mountains. It is about 30 miles long and from 10 to 20 miles wide. The flood waters collect at the north end of the valley in Rush Lake, which covers an area of about 2 square miles. At the south end of the valley a row of low hills composed of indurated

[1] Emmons, S. F., Rept. U. S. Geol. Expl. 40th Par., vol. 2, 1877, p. 464.

[2] Emmons, S. F., Keith, Arthur, and Boutwell, J. M., Economic geology of the Bingham mining district, Utah: Prof. Paper U. S. Geol. Survey No. 38, 1905.

[3] Idem. p. 33.

[4] Emmons, S. F., Rept. U. S. Geol. Expl. 40th Par., vol. 2, 1877, p. 456.



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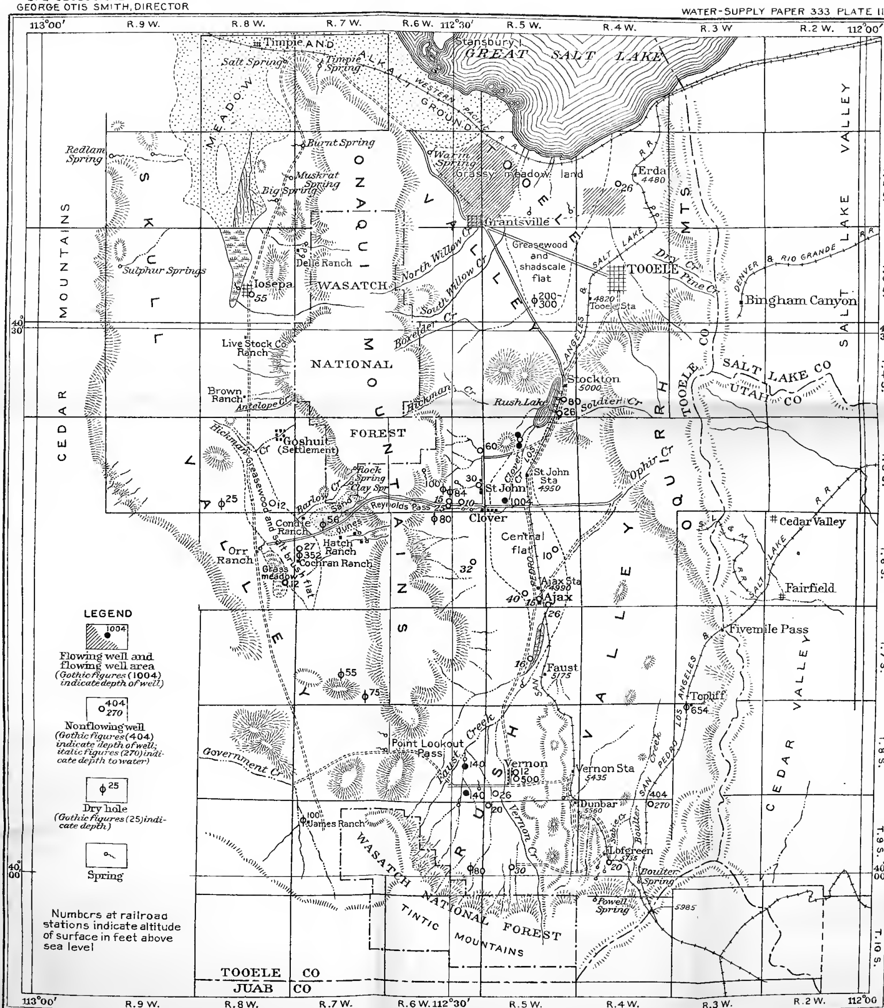

Base compiled from General Land Office plats and railroad alignments

MAP OF THE EASTERN PART OF TOOELE COUNTY, UTAH
SHOWING LOCATION OF WELLS AND SPRINGS

By Everett Carpenter

Scale $\frac{1}{375,000}$

5 0 5 10 15 Miles

1913

THE NORRIS PETERS CO., WASHINGTON, D. C.

strata project northward from the Tintic Mountains. About a mile south of Dunbar siding the San Pedro, Los Angeles & Salt Lake Railroad excavated a cut through these hills, where the following section is revealed:

Section near Dunbar siding.

	Feet.
Disintegrated material, soil, and clay	10
Coarse material	6
Unconformity.	
Clay or shale	15
Fine-grained siliceous sand	55
Massive limestone	150

The strata below the unconformity dip 37° W.

Lake Bonneville occupied only the lower part of this valley, the shore line passing near Stockton, St. John, and Clover and extending within about 10 miles of Vernon. The lake sediments are therefore confined to the lowest levels, the greater part of the slopes consisting entirely of stream deposits. The unconsolidated sediments extend to a depth of more than 1,000 feet, as is shown by the deep well at Clover, which was sunk to that depth.

STREAMS AND SPRINGS.

The lofty mountains surrounding these valleys give rise to a number of streams that have been of great influence in the development of the region, the agricultural settlements of Tooele, Grantsville, Stockton, St. John, Clover, and Vernon owing their existence to them. (See Pl. II.) Pine and Dry creeks, which issue from the Oquirrh Mountains, furnish the domestic and irrigation supplies of Tooele. North and South Willow creeks, which head in the Onaqui Mountains, are led to the town of Grantsville, where their waters are used for irrigation. Soldier and Ophir creeks rise in the southern part of the Oquirrh Mountains and discharge into Rush Valley, Soldier Creek being used for domestic and irrigation supplies at Stockton, and Ophir Creek, which has a flow of about 3 second-feet, being used on the Johnson ranch below the mouth of the canyon. Clover Creek, which rises in Reynolds Pass in the Onaqui Mountains and has a discharge ranging from 14 second-feet in the spring to 3½ second-feet in the fall, supplies water to about 600 acres of land in Clover and St. John. Vernon Creek, which rises in the Tintic Mountains, is used in irrigating about 800 acres along its channel near the town of Vernon. In October, 1911, this stream had a flow of about 5 second-feet.

Some of the springs in the mountains increase the flow of the streams and hence contribute to the irrigation supplies, but many of them do not reach any stream and are useful chiefly as watering places for prospectors and for the stock that grazes in the mountains. There are

two springs in Tooele Valley near Erda, at the foot of the slopes bordering the Oquirrh Mountains, and a number of springs are present in the south end of Rush Valley near Vernon and Lofgreen. All these valley springs furnish small irrigation supplies.

FLOWING WELLS.

Tooele Valley contains two distinct areas of flowing wells—one near Erda covering about 5 square miles, and the other at Grantsville covering about 2 square miles (Pl. II). The Erda area lies at the foot of the alluvial slopes and extends about 2½ miles west into the flat. In this area numerous wells ranging in general from 2 to 4 inches in diameter and from 80 to 300 feet in depth have been drilled, flows being obtained at several horizons. The natural yield of these wells ranges from a very few gallons to 40 or 50 gallons a minute, the deeper beds yielding more than those near the surface. Better yields are also found near the base of the slopes than farther west. The artesian beds are apparently fed by the streams that issue from the mountains back of Tooele and contribute water to the underground reservoirs where they cross the gravelly alluvial slopes. In the Grantsville area there are also many 2 to 4 inch wells obtaining artesian water from sand and gravel beds between 90 and 434 feet below the surface. In general the deeper beds yield more freely than those near the surface. The wells in both areas have been allowed to flow continuously since their completion, with the result that their yield has greatly diminished.

In Rush Valley five wells have been drilled in which the water rises practically to the surface. A well on the farm of Eli Morgan, in the NW. ¼ sec. 9, T. 5 S., R. 5 W., flows about 1 gallon a minute. In the wells drilled on the farms of David Russell, in the SW. ¼ sec. 9, T. 5 S., R. 5 W., and A. J. Stookey, in sec. 32, T. 5 S., R. 5 W., the water rose to the surface but would not flow. Two flowing wells near Vernon are about 140 feet deep and yield about 13 gallons a minute each.

NONFLOWING WELLS.

Very few wells have been put down in Tooele Valley outside of the artesian tracts, the inhabitants being largely congregated in settlements where they use water derived from the mountain streams. A few successful nonflowing wells have, however, been dug along the base of the slopes north of Erda. It would appear from the reports of settlers that it is impossible to obtain ground water in most of the valley. At Tooele a number of wells are reported to have been dug 200 feet deep and at the sink of Boxelder Creek one well is reported to have been sunk 200 to 300 feet, water not being found in either place. Successful wells, however, can doubtless be obtained in the central flat and on the lower part of the alluvial slopes.

In Rush Valley water has been found at shallow depths in several localities. At Stockton the water table is practically at the surface near the margin of the lake but becomes deeper toward the mountains. At St. John and Clover many wells have been dug in which water was found at 25 to 30 feet. At Vernon water was found at 15 to 30 feet in a number of wells along the creek. Successful shallow wells have also been sunk in several other localities, as is shown on the map (Pl. II).

Four deep wells have been drilled in Rush Valley, each of which obtained water. In the Stookey well, in sec. 32, T. 5 S., R. 5 W., water which rose to the surface but did not flow was found at several horizons. This well is 1,004 feet deep and 3 inches in diameter, the casing extending down only 90 feet. In the Vernon test well water was found at several horizons, and that from one of them rose within a short distance of the surface. This well was also 3 inches in diameter and was between 500 and 600 feet deep. In the Delmonte well, in the NW. ¼ NE. ¼ sec. 2, T. 9 S., R. 4 W., 1¼ inches in diameter and 404 feet deep, the water rose to a level of 270 feet below the surface. The water is lifted by a 2-horsepower Fairbanks-Morse gasoline engine. The Toplif well, in the NE. ¼ NE. ¼ sec. 6, T. 8 S., R. 3 W., is 5½ inches in diameter and 654 feet deep. The log of this well is given on page 24. The water is warm but of good quality and is lifted by a steam-propelled 36-inch Cook pump, the water being used at the Toplif quarries.

GROUND-WATER PROSPECTS.

A part of the water falling as rain or snow on the mountains surrounding Tooele and Rush valleys is discharged through the canyons, sinks into the coarse beds of the alluvial slopes, and travels toward the central flats, where it accumulates so near the surface that it is wasted by evaporation. Wells that will furnish good water can be sunk in these water-bearing beds, but on the upper and middle parts of the slopes the water table probably lies rather deep; and trouble would be experienced in drilling on account of the large bowlders in the underlying material. If drilling machinery that is capable of sinking a hole of relatively large diameter to considerable depth is used, there will be less likelihood of having the hole deflected or the drilling stopped by bowlders than if it is done with light hydraulic rigs.

SKULL VALLEY.

TOPOGRAPHY AND GEOLOGY.

Skull Valley lies west of the Onaqui or Stansbury Mountains and is a broad arm of the Salt Lake depression. At its north end it is occupied by extensive marshes that are scarcely above the level of

the lake. Farther south it rises gradually to an almost imperceptible divide opposite Point Lookout Pass, south of which the drainage is thrown westward into Great Salt Lake Desert.

The Onaqui Mountains, which form the eastern boundary of this valley, are discussed in connection with the description of Tooele Valley (p. 76). The Cedar Mountains,[1] which lie west of the valley, rise about 2,000 feet above the valley floor and consist chiefly of Paleozoic strata that dip eastward at various angles. The Lakeside Mountains lie north of the Cedar Mountains and form a part of the northwest boundary of the valley. The Tintic Mountains extend westward across the south end of the basin and separate it from the Sevier Desert basin.

The structural trough comprising this valley has been partly filled by stream, lake, and wind deposits. The stream deposits are confined mainly to the alluvial slopes. The slopes bordering the Onaqui Mountains are high and gravelly, but those bordering the Cedar Mountains are low and descend gradually to the lowest part of the valley. Lake Bonneville occupied practically all of the valley. At the north end this ancient lake was about 1,000 feet deep, but opposite Point Lookout Pass the water was shallow, forming fancifully shaped beach ridges on the low divide. The wind deposits are confined to a small area along Barlow Creek. Loose sands have been blown from the desert and deposited on the alluvial slopes in this locality, producing a dune topography.

The stream and lake deposits in this valley extend to an unknown depth. The deepest well is 350 feet deep and appears to end in Lake Bonneville sediments. A dry hole dug on the James ranch passed through about 100 feet of coarse gravel and bowlders, which were evidently stream deposits.

PRECIPITATION.

Data on precipitation have been taken at Government Creek (James ranch) for a period of about 12 years and at Iosepa since September, 1910. The average annual precipitation at Government Creek is 11.53 inches. The monthly data on precipitation at these two stations have been plotted in figure 9 for the period since the installation of the Iosepa station. This diagram shows that there is a very close relation between the rainfall in the north and south ends of this valley, the curves being in many parts almost coincident. The most rain falls in the first four months of the year and the least in the second four months.

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[1] Emmons, S. F., Rept. U. S. Geol. Expl. 40th Par., vol. 2, 1877, p. 462.

VEGETATION.

The highest parts of the Onaqui Mountains contain a large amount of pine and cedar and are included in the Wasatch National Forest. The Cedar Mountains and the upper portions of the alluvial slopes

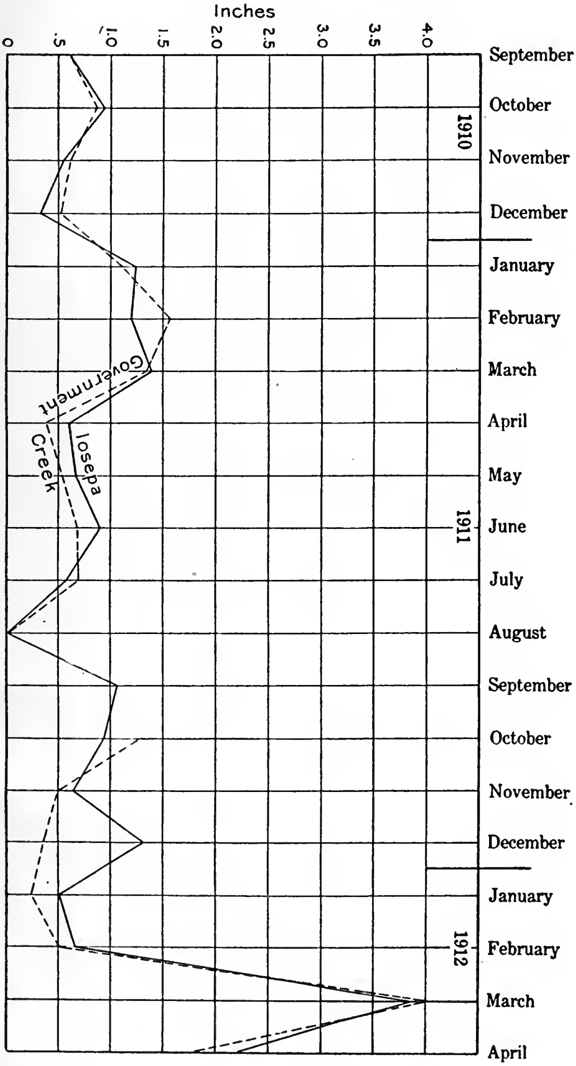


FIGURE 9.—Diagram showing relation of precipitation at Iosepa and Government Creek (James ranch), Utah.

adjacent to the Onaqui and Cedar mountains support a scant growth of sage brush and juniper; the lower portions of the alluvial slopes produce stunted white sage, match brush, and shadscale, and the central flat is covered by greasewood and swamp grasses.

STREAMS AND SPRINGS.

The only permanent streams in Skull Valley are Barlow, Hickman, Antelope, and Lost creeks, which rise in the Onaqui Mountains north of Reynolds Pass and flow into the valley where their waters are used on the ranches located along their courses. (See Pl. II.) Barlow Creek flows to Condie's ranch, where it furnishes water for irrigating about 45 acres. Hickman Creek flows to the Goshuit Indian settlement, where its waters are all appropriated. Antelope Creek flows to Brown's ranch, where about 100 acres are irrigated with its waters. Lost Creek has been led to the Live Stock Co.'s ranch for irrigation, domestic use, and stock supply. At Orr's ranch, in sec. 6, T. 6 S., R. 8 W., a number of springs yield enough water to irrigate about 80 acres. At the Hatch ranch, in sec. 9, T. 6 S., R. 7 W., springs are also used for irrigation. At Iosepa settlement a number of springs, which occur at the base of the mountains, have been developed for irrigation, domestic use, and stock supply. Big, Burnt, and Muskrat springs, which lie along the wagon road leading north to Iosepa settlement, are so poor in quality that they can not be used for irrigation, especially on the alkali ground where they issue.

Government Creek is a dry run in which the water flows only during floods. One of its tributaries that rises in the Tintic Mountains, however, has a permanent supply which has been led to the James ranch, where it is used for irrigation, domestic purposes, and stock.

GROUND WATER.

Most of the ranches depend on surface water for domestic supply, and there has therefore been but little development of ground water in this valley. Water was found at 12 feet in the NE. ¼ sec. 35, T. 5 S., R. 8 W. In the 350-foot well of T. S. Cochran, in sec. 18, T. 6 S., R. 7 W., water of inferior quality was found at 30 feet, but no other water-bearing stratum was encountered. In a well at Iosepa settlement, 55 feet deep, water was found that is too brackish to be used for culinary purposes. At the James ranch, on Government Creek, an excavation was carried to a depth of 100 feet through coarse gravel and bowlders, but no water was found.

Although only a few wells have been dug in this valley, it is not improbable that good water can be obtained from wells, especially on the lower slopes bordering the Onaqui Mountains. The luxurious timber on these mountains indicates a heavy rainfall. The surplus water flows from the canyons over the alluvial slopes, where a part sinks into the loose gravelly material and finds its way beneath the valley. The water table probably lies deep beneath the surface in a large part of the valley and in the porous sand area along Barlow

Creek, the lower slopes north of Reynolds Pass offering the most favorable indications of furnishing ground water. The most practical method of obtaining wells will be by using drilling machinery capable of sinking through gravel and bowlders to a considerable depth.

WATERING PLACES ON ROUTES OF TRAVEL.

The following information is given for the benefit of persons who are strangers to this region but who wish to make a journey to some part of it or who wish to pass through it on a transcontinental automobile tour. In connection with these directions Plates I and II should be consulted. It should be remembered that changes are made from time to time, and that watering places in use at one time may later fall into disuse. Before starting on a journey, therefore, the directions here given should be supplemented by information from local sources.

BOXELDER COUNTY.

RAILWAY STATIONS AND THEIR CONNECTIONS.

On the map of this country (Pl. I, in pocket) stations are indicated at intervals of several miles along the railroads, but many of these stations are merely switch yards and water tanks with no inhabitants and no food or shelter, and some are merely switch yards to accommodate passing trains. The stations in lower Bear and Malad River valleys are small towns containing hotel and other accommodations, but in the other valleys only Promontory, Promontory Point, Kelton, and Lucin contain inhabitants.

The main line of the Southern Pacific Railroad crosses Great Salt Lake and the northern part of Great Salt Lake Desert west of Promontory Point, leaving the State of Utah west of Lucin. A stage line connects Lucin with Grouse Creek and it will be possible to obtain a conveyance at Lucin for points to the south.

The old line of the Southern Pacific, formerly the Central Pacific Railroad, extends from Brigham to Lucin by way of Promontory and Kelton, but trains are operated only between Brigham and Kelton, the runs being made on Tuesdays, Thursdays, and Saturdays. Kelton is the supply station for Park Valley and the southern and western parts of Curlew Valley. A stage runs between Kelton and Rosette. Promontory is the supply station for Hansel Valley and the lower part of Blue Spring Valley.

The Oregon Short Line Railroad Co. operates two lines in lower Bear and Malad River valleys. The main line of this system follows the west flank of the Wasatch Mountains through Willard, Brigham, Honeyville, Deweyville, and Collinston, entering Cache Valley through

the Bear River canyon in the Wasatch Mountains. A branch line goes from Brigham to Corinne, and thence north to Malad, Idaho, passing through Tremonton and Garlin and near the towns of Bear River City, Riverside, Fielding, Plymouth, and Portage. A stage line is operated between Tremonton and Showell by way of Blue Spring and Snowville.

WAGON ROADS.

Two main wagon roads connect Brigham with Kelton, one by way of Promontory and the other by way of Snowville. In dry weather they are equally good, but in wet weather the Snowville route is much the better.

Brigham to Kelton via Promontory.—The road leading west from Brigham to Kelton follows closely the old line of the Southern Pacific Railroad. It passes several watering places in Lower Bear River valley, the last before reaching Promontory being Blue Creek, where water has been piped to the railroad for locomotive supply. Near Promontory the road forks, the best-traveled route leading past Rozel and Cedar Spring, and the other leading directly to Cedar Spring. The road from Cedar Spring to Kelton passes Salt Wells, Monument, and Locomotive Springs. Water may be procured for camp use at each of the places mentioned, but that from Salt Wells and Locomotive Springs is undesirable for drinking.

Brigham to Kelton via Snowville.—The wagon road from Brigham to Kelton by way of Snowville leaves the Southern Pacific Railroad at Corinne and passes up the valley to Tremonton, where it turns west and leads across the Blue Spring Hill to Blue Spring. Thence it leads up Blue Spring Valley, across the Promontory Range to the head of Hansel Valley, past Dillies Spring to Snowville. The telephone line between Tremonton and Snowville will be a valuable guide to strangers in keeping the road. From Snowville the road leads almost due west to Showell, whence it takes a southwest course to Kelton. Water may be obtained at Tremonton, Blue Spring, Snowville, and Showell, and at a number of farmhouses in lower Bear River valley and Blue Spring Valley, but there are no watering places between Showell and Kelton.

Kelton to Lucin.—Two wagon roads lead between Kelton and Lucin. One road follows the old railroad line and the other leads through the southern part of Park Valley. On the road following the railroad, water can be obtained at Terrace, where the railroad company maintains a supply piped from Rosebud Creek for locomotive use in emergencies when through trains are run over the old line. The other wagon road leads nearly due west from Kelton until it crosses Dove Creek, whence it takes a southwest course around the south end of the Grouse Creek Mountains. Water can be procured on this road at Dove and Muddy creeks.

Kelton to Park Valley, Raft River valley, and Snowville.—The road from Kelton to Park Valley leads northwest over the Kelton escarpment. Water can be had at the springs in sec. 10, T. 12 N., R. 12 W., but as it is only 13 miles from Kelton to the Park Valley store the trip is usually made without taking water on the way. In going from Kelton to Raft River valley or points beyond, water can be obtained at the Rose ranch, sec. 8, T. 12 N., R. 11 W., and at Cedar Store, sec. 12, T. 14 N., R. 12 W. The road from Kelton to Snowville passes no watering places until it reaches Showell, which is only a few miles from Snowville.

Park Valley to Grouse Creek and Junction Creek.—The road from Park Valley to Grouse Creek leads west through Rosette to Indian Farm, thence south to Warm Spring, thence west to the head of North Birch Creek, and thence across the Grouse Creek Mountains, descending on the west side of the range along a branch of Mahogany Creek. Water can be obtained at Rosette, Indian Farm, Warm Spring, and Birch Creek. The road across the mountains is so steep and rough that it can not safely be traveled by an automobile or a loaded wagon.

The road to South Junction Creek leaves the Grouse Creek road at Indian Farm and follows up Dove Creek to the top of the pass between the Raft River and Grouse Creek Mountains. Beyond the pass it descends as a rather rough trail to South Junction Creek. Water is plentiful along Dove Creek, but there is no water along the road between the pass and South Junction Creek.

Snowville to east and west arms of Curlew Valley, Raft River valley, and Park Valley.—A well-traveled wagon road traverses the east arm of Curlew Valley between Snowville and Holbrook. This part of Curlew Valley is well settled and water can be obtained from numerous farm wells and from Deep Creek.

The best road to the west arm of Curlew Valley leads west through Showell, then northwest to the line of springs on the west side of T. 16 S., R. 30 E. No water is obtainable in this arm except along the slope bordering the Black Pine Mountains and at one spring in sec. 31, T. 14 S., R. 30 E.

The trip from Snowville to Raft River is best made by way of Showell and Cedar Store. Water can be procured at Showell, Pilot Spring (in sec. 13, T. 14 N., R. 11 W.), and Cedar Store. Northwest of Cedar Store the road leads through Clear Creek settlement, where water can be obtained.

There are two routes from Snowville to Park Valley, one leading due west from Showell and the other southwest from that place. The roads reunite at the Kelton escarpment and lead west across Indian Creek to Park Valley Store. The road leading west from Showell goes to Pilot Spring, which is a favorite camping place. At the spring

the road turns toward the southwest. The other road, which leads nearly due southwestward from Showell, passes a spring about 10 miles from Showell, but this spring is easily passed without being seen. It is, moreover, fit only for stock use.

Lucin to Wendover and Ibapah.—A wagon road leads from Lucin to Ibapah, a distance of about 100 miles, by way of Wendover, a station on the Western Pacific Railway, at which accommodations and supplies can be obtained. This road runs east of the Tecoma and Pilot mountains, passing a series of springs which begin about 15 miles south of Lucin and extend to Morrison's ranch, in sec. 36, T. 4 N., R. 19 W. Water can be procured at some of these springs, at McKellar's ranch, in sec. 12, T. 3 S., R. 19 W., and at Hall's Spring, 3 miles farther south. The road from McKellar's ranch to Wendover crosses the edge of the desert flat and follows the pipe line into Wendover. From Wendover to Ibapah, a distance of about 55 miles, the road leads past Salt Spring and along Deep Creek. A stage runs three times a week from Wendover to Ibapah and Calleo.

Lucin to Grouse Creek.—Grouse Creek may be reached from Lucin by the stage which travels three times a week between those places. The road follows up the valley and does not pass any watering places except near the settlement.

TOOELE COUNTY.

RAILWAY STATIONS AND THEIR CONNECTIONS.

The San Pedro, Los Angeles & Salt Lake Railroad crosses the eastern part of Tooele County. It traverses Tooele and Rush valleys, passing through Erda, Tooele, and Stockton and near St. John, Ajax, Vernon, and Lofgreen. Stage connections are made with St. John, Clover, and Vernon. Water can be obtained at each of these places.

The Western Pacific Railway passes around the south end of Great Salt Lake and crosses the north end of Skull Valley; thence it leads west across the Great Salt Lake Desert, entering Nevada near Wendover. This railroad passes through no towns where accommodations can be obtained. The desert is uninhabited and is, in large part, an impassable waste. A station and water tank are maintained at Temple, about 15 miles north of Iosepa, but there are no stage connections between this station and the settlements in Skull Valley.

WAGON ROADS.

Skull Valley may be reached from Tooele or St. John. The road from St. John leads across the Onaqui Mountains, through Reynolds Pass, to Orr's ranch. Watering places are plentiful along the route.

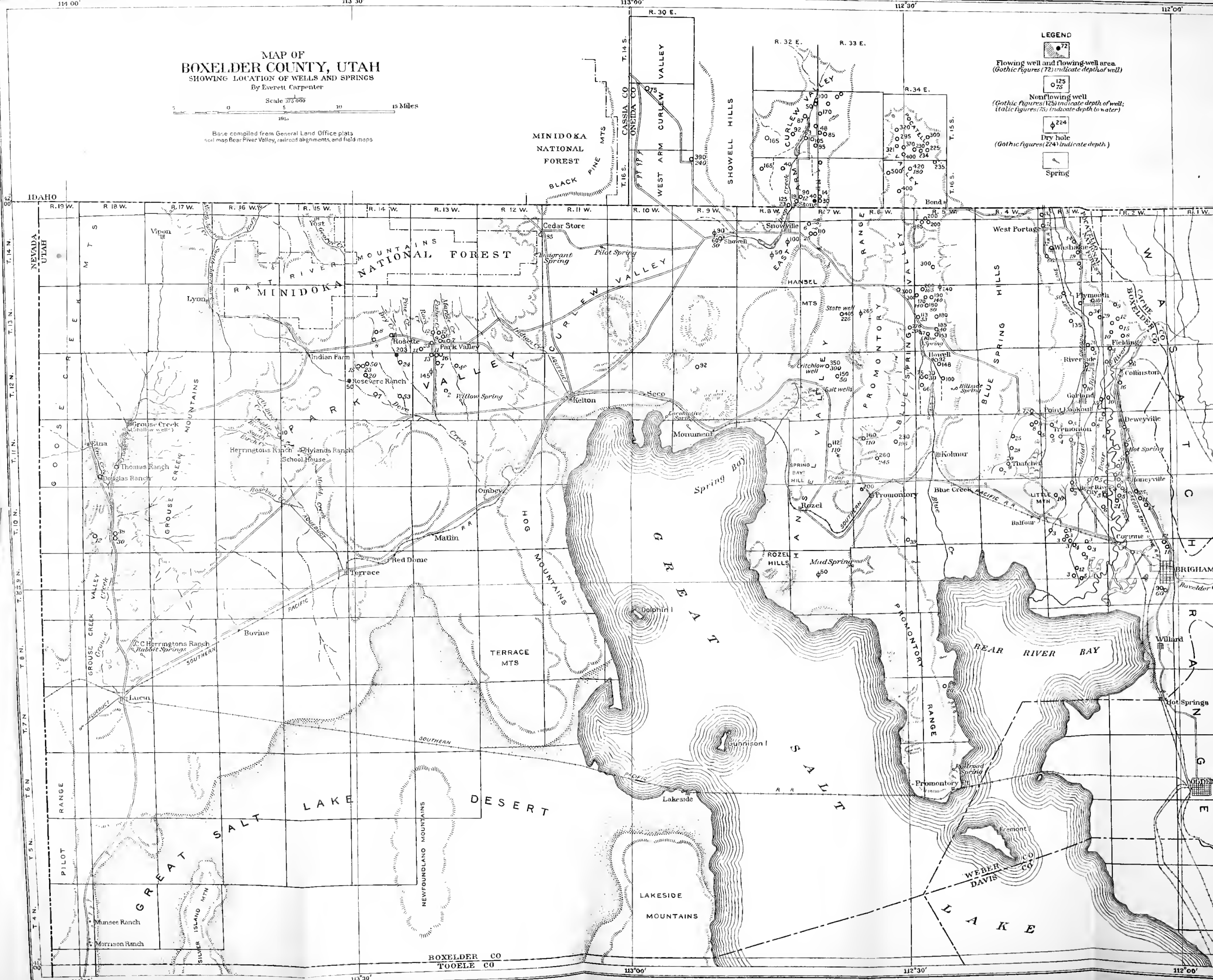
The north end of Skull Valley is best reached from Tooele, over a road that leads through Grantsville, past Timpie Spring, at the north end of the Onaqui Mountains, and thence southward past Big, Burnt, and Muskrat springs, to Iosepa. Water can be obtained at each of the springs mentioned.

A stage line goes from Vernon to the James ranch, Dugway, the Utah mine, Calleo, and Ibapah, but this route passes few watering places and most of its course is through an uninhabited region.

Distances in miles between principal watering places on routes of travel in Boxelder County, Utah.

	Brigham.	Corinne.	Blue Creek.	Promontory.	Rozel.	Salt wells.	Kelton.	Terrace.	Lucin.	Collinston.	Plymouth.	Portage.	Bond.	Blue Springs.	Snowville.	Showell.	Cedar Store.	Park Valley.	Grouse Creek.
Brigham	0	6	23	35	42	46	73	120	135	20	28	40	52	40	60	67	85	86	160
Corinne	6	0	16	29	34	40	67	114	130	18	21	36	48	37	54	61	79	80	154
Blue Creek	22	16	0	8	16	23	48	75	100	....	....	....	....	....	....	....	....	....	....
Promontory	35	29	8	0	8	15	40	70	93	....	....	....	....	....	....	....	....	....	....
Rozel	42	34	16	8	0	13	32	62	85	....	....	....	....	....	....	....	....	....	....
Salt Wells	46	40	23	15	13	0	25	55	78	....	....	....	....	....	....	....	....	....	....
Kelton	73	67	48	40	32	25	0	30	60	....	....	....	....	....	32	25	17	13½	....
Terrace	120	114	75	70	62	55	30	0	23	....	....	....	....	....	....	....	....	....	....
Lucin	135	130	100	93	85	78	60	23	0	....	....	166	....	....	92	85	82	62	25
Bear River City	12	6	....	....	....	....	....	....	....	15	14	32	44	....	48	55	73	74	148
Honeyville	10	8	....	....	....	....	....	....	....	10	17	31	43	....	....	....	....	....	....
Deweyville	15	13	....	....	....	....	....	....	....	5	11	26	38	....	....	....	....	....	....
Collinston	20	18	....	....	....	....	....	....	....	0	7	21	33	....	....	....	....	....	....
Tremonton	20	12	....	....	....	....	....	....	....	10	13	23	35	23	40	47	65	100	133
Garland	24	14	....	....	....	....	....	....	....	....	10	20	32	23	40	47	65	100	133
Plymouth	28	21	....	....	....	....	....	....	....	7	0	13	25	....	....	....	....	....	....
Portage	40	36	....	....	....	....	....	....	....	21	13	0	12	....	....	....	....	....	....
Bond	52	48	....	....	....	....	....	....	....	33	25	12	0	13	....	....	....	....	....
Blue Spring	43	37	....	20	....	....	....	....	....	33	36	46	13	0	18	25	43	60	97
Howell	40	35	13	16	....	19	....	....	....	33	36	49	16	3	21	28	46	63	100
Snowville	60	54	....	30	....	16	32	....	92	....	....	....	....	18	0	7	25	42	79
Showell	67	61	....	37	....	23	25	....	85	....	....	....	....	25	7	0	18	35	72
Cedar Store	85	79	....	....	....	....	17	....	....	....	....	....	....	43	25	18	0	20	57
Park Valley	86	80	....	....	....	....	13½	....	....	....	....	....	....	60	42	35	20	0	37
Rosette	90	84	....	....	....	....	18	....	....	....	....	....	....	64	46	39	24	4	33
Grouse Creek	160	154	....	....	....	....	....	....	25	....	....	....	....	97	79	72	57	37	0

INDEX.



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